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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXI.—*The Velocity of the Propagation of Magnetism;* by Henry A. Perkins.

The effect of self-induction in a circuit causing a retardation in the establishment of a magnetic flux is of course well known to everyone; but an allied effect, caused not by the inductance between coil and magnetic circuit, but in the magnetic circuit itself, thus causing a very perceptible interval of time between the appearance of the magnetism at two points, has not been so thoroughly studied, although it must be present in all alternating current machinery to a certain degree. This retardation is thus due to the eddy currents in the core of the magnet in question and is a complicated function of the various physical properties of the core, the frequency and magnitude of the impressed electromotive force.

This phenomenon was first investigated in detail by Oberbech* in 1884. His apparatus consisted in a core with magnetizing coil. Beside this coil were two others whose distance apart could be varied at will. To measure the phase angle between the electromotive force generated in these coils when a sinusoidal e.m.f. was impressed on the main coil, he made use of a dynamometer, the fixed coil being in series with one of the sliding coils, and the movable one with the other. The resulting deflection he showed to be a function of various known quantities and some unknowns that were eliminated by repeating the experiment with added resistance in series with one of the two circuits, thus obtaining a different deflection. This was repeated at different distances up to 20^{cm}. His results show values of the lagging angle from 2° 16′, when the distance was

* Wied. Ann., xxii, p. 73.

10^{cm} and the core a bundle of 64 small steel wires, up to 96° 12′ in 10^{cm} for a steel bar of $1{\cdot}2^{cm}$ diameter. This shows at least qualitatively what we should expect, that lamination reduces the lag. The curves of flux intensity taken along the bar appeared to be logarithmic curves whose equation was $Q = Q_o e^{-\beta x}$. β varied somewhat, and his results were tabulated as follows:

$$\beta \text{ for soft iron} = \begin{cases} 10{\cdot}27 \\ 10{\cdot}17 \\ 10{\cdot}07 \end{cases}$$

$$\beta \text{ for hard iron} = \begin{cases} 14{\cdot}8 \end{cases}$$

$$\beta \text{ for steel} = \begin{cases} 14{\cdot}51 \\ 16{\cdot}16 \\ 16{\cdot}37 \end{cases}$$

x being measured in meters. In conclusion, the author says that the size of β varies only as the material and is independent of the diameter. This is also true of direct current phenomena; hence he argues that were it not for the opposition of eddy currents the velocity would be enormous.

When I first began investigations on this effect I was not aware of the work just cited. But inasmuch as the results were somewhat of a qualitative nature, and the method used is open to serious objection, I thought it worth while to continue the research.

The method employed was in some respects similar to that of Oberbech. A magnetizing coil was mounted on the center of a steel bar about one meter long and having a section of $2{\cdot}83^{cm^2}$. It was of the best English tool steel. This material was used in order to obtain as low a velocity as possible and thus measure it more readily. On the middle of the magnetizing coil were wound 250 turns of fine wire, and sliding on the core were two more coils, one of 500 turns and one of several thousand. As will be seen, the exact number is not an essential quantity.

In performing the experiment one of the movable coils was set at some known distance from the exciting coil at the center, and the angle of lag between it and the small coil of 250 turns was measured. For short distances, up to about 8^{cm}, one of 500 turns was used; beyond that the larger coil. The instrument by which this angle was measured was a small quadrant electrometer having double quadrants and an aluminum needle suspended by a quartz fiber and dipping into sulphuric acid through which the contact was made. The needle and one pair of quadrants constituted one terminal and the other pair of

quadrants the other. By means of two Kempke discharge keys the circuits were so arranged that the electrometer was normally on short circuit, but on pressing the keys simultaneously the terminals of the external circuit were simultaneously attached to the electrometer terminals. This method was essential, for with one terminal free and the other connected to some metal object the instrument would be most violently deflected; hence the necessity for making the contacts exactly together.

As it was purposed to measure alternating voltages, the instrument was calibrated with the use of alternating e.m.f. of the

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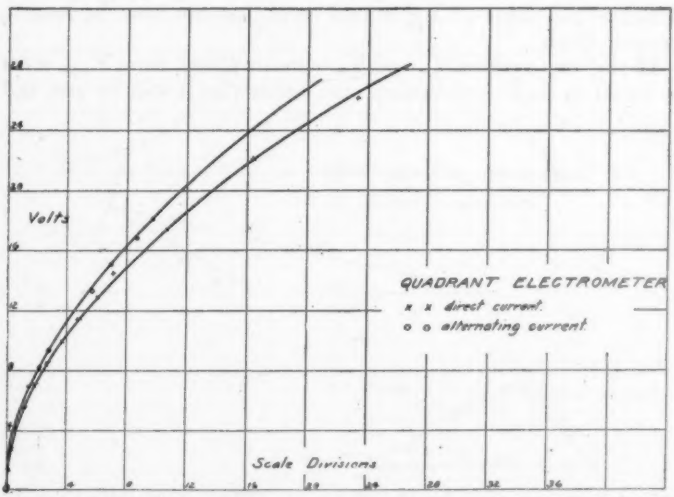

same frequency. These were measured by "weighing" in a Kelvin balance the current that went through a non-inductive resistance across whose terminals the electrometer was connected. The resistance was measured after each reading to allow for possible changes due to heating. It may be of interest to note that the calibration curve as obtained by this method differed considerably from one obtained with constant voltages. This was doubtless due to the capacity introduced by the cup of sulphuric acid into which the needle dipped.

Several readings were necessary in determining a single angle. Calling the small central coil wound on the exciter "A," and the more distant coil "B," we may simplify the description as follows: The electrometer was first connected to A, giving a deflection D_a which corresponded to an induced potential V_a.

Next by connecting to B, D_b and thus V_b was obtained. Then by connecting A and B in series in such a way that they were in accord, V_{a+b}, and finally when opposed $V_{a'-b}$, were observed. The accent above "a" in the last quantity refers to the necessity of reversing the connections of A (or B), and, strangely enough, the deflection given by any coil was slightly altered on reversal. The reason for this I was unable to determine, unless, indeed, it is due to inequalities between the positive and negative loops of the commercial current which was used. This seems unlikely, and I purpose to investigate the matter further. This effect was not harmful if properly observed and allowed for.

With the four readings just referred to it was possible to calculate the angle of lag in two ways that can best be seen in graphic form.

If the two vectors V_a and V_b were in phase, then V_{a+b} must be equal to their arithmetical sum, otherwise it will be less, and

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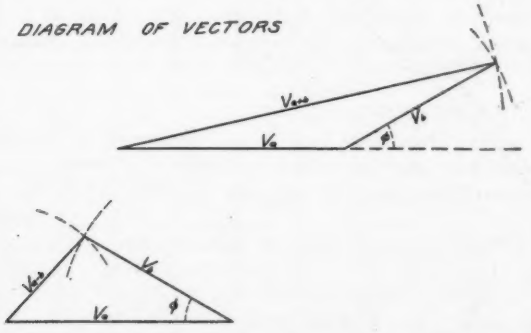

this was always found to be the case. The construction can be seen from a glance at the diagram, which gives us ϕ, or the angle of lag. Similarly with the two coils opposed, $V_{a'-b}$ will be greater than the arithmetical difference of $V_{a'}$ and V_b, as shown above. In the results recorded here the latter method was used as being less liable to error, for it involved no large deflection like D_{a+b} and for small values of ϕ it is also true from trigonometrical reasons.

Determinations of ϕ were made at intervals up to nine inches from the central coil, and from these values the velocities for the parts in question were calculated. From inspection of the curve it is clear that $\frac{d\phi}{dx}$ is not a constant, hence the velocity cannot be constant. The velocity at any point in the bar was found from the angle curve by observing the change in lag for a short distance on either side of the point in question. Calling

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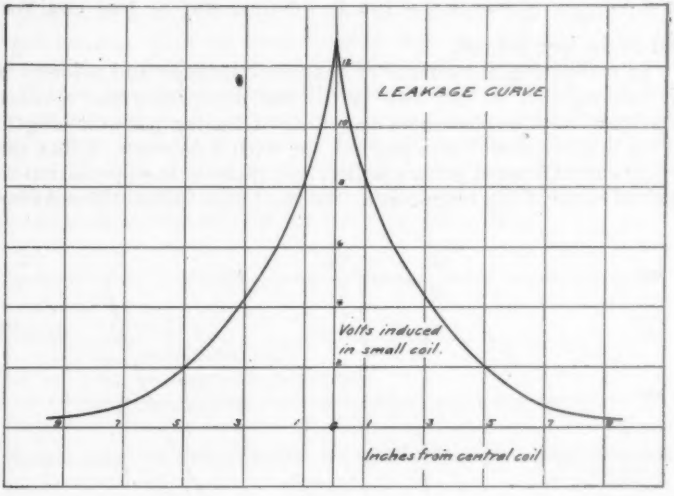
LEAKAGE CURVE
Volts induced in small coil.
Inches from central coil

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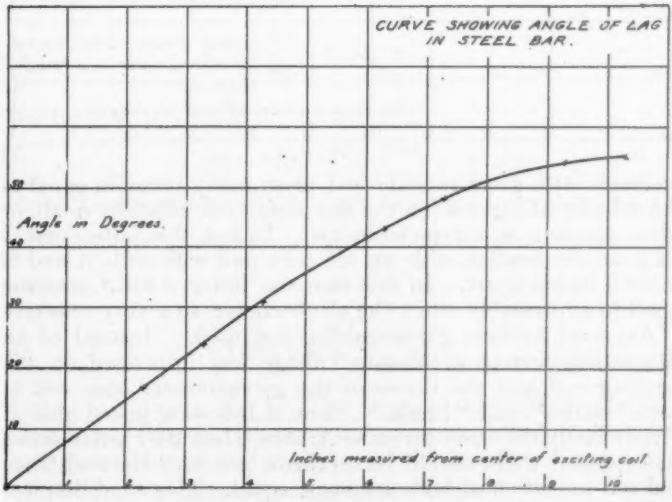
CURVE SHOWING ANGLE OF LAG IN STEEL BAR.
Angle in Degrees.
Inches measured from center of exciting coil

this distance "d" and the angular difference "δ," we have $v = \frac{360 \cdot d \cdot n}{\delta}$, where n = the frequency, and in this case was 60 cycles per second.

In comparing the curves of magnetic leakage and velocity it is evident that as the flux in the bar diminishes the velocity increases with a consequent lessening of the lag per unit length. This is what would be expected, for with a decrease of flux the eddy currents must grow smaller, and there is less opposition to the advance of the magnetism. Beyond nine inches the velocity

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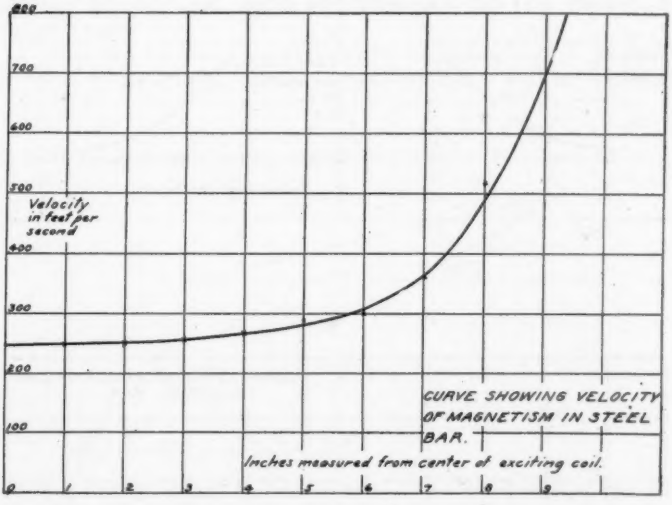

increases with great rapidity and presumably becomes equal to the velocity of light when the flux density is infinitely small, or when the core is a non-conductor. To test this latter case I made an observation with an air core, and with coils A and B about 6 inches apart. In this case the induced e.m.f. was too small to appreciably affect the electrometer, so a very sensitive D'Arsonval ballistic galvanometer was used. Instead of an alternating current a constant voltage was impressed on the exciting coil and the throw of the galvanometer observed at both "make" and "break." Now if B is so adjusted that it gives exactly the same throw as A, then when they are in series and opposed there should be no throw provided the resistance and self-induction of both are made equal. This condition was fulfilled by adding an external coil in series with A, thus mak-

ing that circuit similar to that of B. The result, as expected, was no deflection, although so sensitive was the apparatus that a change of one millimeter in the position of B overthrew the equilibrium. This at least showed that the velocity must be exceedingly great as compared to that in the steel bar.

It only remains to show that the mathematical theory predicts results similar to that observed. In an article by J. Zennech,* the author develops the theory of the propagation of magnetism, which, though it takes no account of hysteresis, should give at least approximate values when properly used. The fundamental equation is similar to that for variable currents:

$$(1) \qquad Q w_m = -\frac{\delta V_m}{\delta x} - p_m \frac{\delta Q}{\delta t},$$

where Q = flux,
w_m = reluctance,
V_m = magnetic potential,
p_m = coefficient of self-induction of the core.

By applying the law that the rate of leakage is proportional to V_m, i. e.

$$(2) \qquad C_m = -\frac{\delta Q}{\delta x} \Big/ V_m,$$

where C_m is the magnetic analogue of capacity, and combining (1) and (2), the equation (3) is obtained:

$$(3) \qquad C_m p_m \frac{\delta Q}{\delta t} + C_m w_m Q = \frac{\delta^2 Q}{\delta x^2},$$

whose solution must be of the form:

$$(4) \qquad Q = Q_o e^{-\beta x} \cdot e^{i(\pi n t - \gamma x)},$$

where β is the damping factor, n = twice the frequency and $\gamma = \frac{\pi n}{v}$, v being the desired velocity. This solution satisfies the equation when

$$(5) \qquad \beta^2 - \gamma^2 = C_m \cdot w_m$$
$$(6) \qquad \text{and } 2\beta\gamma = C_m \cdot \pi n p_m.$$

To find v it is necessary to know three of the quantities, β, C_m, w_m and p_m. As p_m presents the greatest difficulty, the first three were selected by the author of this article. β was deter-

* Drude's Ann., 1903, No. 4, p. 845.

mined directly from the leakage curve, assuming it to be fairly well represented by the equation $\beta = \log \frac{Q_o}{Q_x} \Big/ x$. The average value was ·16, which gives a curve fitting the original fairly well near its middle point. This agrees quite closely with Oberbech's value for steel; the difference in the position of the decimal point is due to his choice of the meter as the unit of length instead of the centimeter.

The calculation of C_m is more difficult, particularly as Dr. Zennech is not quite explicit in explaining V_x; but I venture to suggest the following method as applied to a point four inches from the center of the exciting coil. The difference of potential of the two faces of a coil of n turns carrying a current I is $\frac{4\pi n I}{10}$ as determined by the amount of work done in carrying a unit pole from one face around outside the coil to the other. This work would be increased if the medium were of greater permeability than air; moreover, the work done would be half the total if the unit pole were carried only from one face to the far end of the bar, where the flux is almost zero. The fall of potential would then vary as Q along the bar. From these considerations I calculated V_x by the following equation:

$$V_x = \frac{4\pi n I}{10} \cdot \mu \cdot \frac{Q_x}{2Q_o} = 27,$$

where $n = 4077$ (No. turns in coil),
$I = \cdot 015$ ampères,
$\mu = 2 \cdot 95$,
and $\frac{Q_x}{Q_o} = \frac{3 \cdot 1}{12 \cdot 9}$, as may be seen from the leakage curve.* The value of μ was found by carefully measuring the resistance of the exciting coil and the currents flowing in it under an alternating pressure of 120 volts, when the steel core and an air core were successively used. The impedance in one case was 7998 ohms, in the other 2727. Knowing the resistance and the frequency, it was easy to calculate the coefficient of self-induction for iron (L_i) and for air (L_a), and $\mu = \frac{L_i}{L_a}$.

Referring to equation (2) we still have $\frac{\delta Q}{\delta x}$ to determine, which can be done readily by differentiating $Q = Q_o e^{-\beta x}$ and substituting the values of Q_o, β and x. β has been determined, $x =$

* These and other values were taken from the original curves as plotted in the laboratory. Those prepared for photographic reproduction give the general form correctly but are not strictly accurate copies.

$10{\cdot}16^{cm}$, and Q_o is found from the equation $Q_o = \frac{10^8\sqrt{2}E \cdot 2}{\pi n w}$, where $E = 12{\cdot}9$, $n = 500$, $w = 377$, and Q_o is the average value of the flux at the center of the exciting coil. Hence $\frac{\delta Q}{\delta x} = -Q_o\beta e^{-\beta x} = -\frac{6146 \times {\cdot}16}{e^{1{\cdot}63}} = 193$. Finally $C_m = -\frac{\delta Q}{\delta x}\Big/V_x = \frac{193}{27}$, the negative sign vanishing because $\frac{\delta Q}{\delta x}$ is negative.

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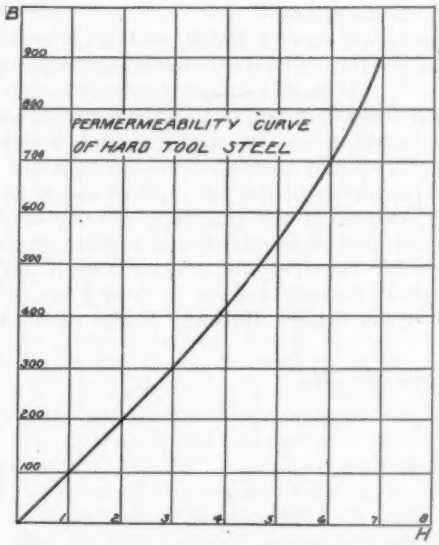


The average flux density at a point four inches from the center is 522 lines per square centimeter, obtained similarly to Q_o above, and the permeability at this density was found to be 110, as shown in the permeability curve of the bar used.* This gives the reluctance per unit length as $w_m = \frac{1}{110 \times 2{\cdot}83}$; $2{\cdot}83$ being the cross section of the bar.

We are now in a position to make the final calculation, employing equation (5) and solving it for γ, which is equal to $\sqrt{\beta^2 - C_m w_m}$. We have $\gamma = {\cdot}0513$ and $v = \frac{\pi n}{\gamma} = 7336^{cm}/_{sec}$ or

* The author owes sincere thanks to Messrs. E. E. Moran and D. H. Miller, students in Yale University, for the determination of the BH curve of the steel bar.

$245^{ft}/_{sec}$ as against $257^{ft}/_{sec}$ actually observed. It must be admitted that values of v calculated for other points along the bar did not agree so closely with observation, those nearer the center being too small and those farther out too large; but considering the fact that equation (5) makes γ exceedingly sensitive to very small errors in the values β, C and w, a closer agreement could hardly be expected.

A more approximate method suggested by Zennech gives $\beta/\gamma = 2{\cdot}4$ for cases of moderate permeability and frequencies of about fifty cycles. Using $\beta = {\cdot}16$ this gives $v = 5712^{cm}/_{sec}$, which is as close as could be expected from the approximate nature of the assumptions.

In conclusion we may, I think, accept as proved that the velocity of magnetism in metallic paths, and especially those of high permeability, is small compared to that in non-conducting bodies. That this effect is due to eddy currents and therefore variable, diminishing as the flux diminishes along the bar. That this velocity is not a simple function of x, but depends on the physical properties of the bar, such as ohmic resistance and permeability, as well as the magnetic density at the point in question. And that this retardation is great enough to cause a very perceptible lag where the density is high and the lamination poor; great enough indeed, it would seem, to call for recognition in the design of many forms of electromagnetic machinery.

Trinity College, July, 1904.

ART. XXII.—*The Geomorphic Origin and Development of the Raised Shore Lines of the St. Lawrence Valley and Great Lakes;* by R. CHALMERS, LL.D., of the Geological Survey of Canada.

[Published by permission of the Acting Director of the Geological Survey.]

IN a paper published by the writer in 1896 on the "Pleistocene Marine Shore Lines on the South Side of the St. Lawrence Valley,"* and in an official report issued in 1897,† it was shown that the valley referred to and the region of the Great Lakes must have stood at a lower level at the close of the Pleistocene‡ than at the present day, the movements of the ice in the glacial period and the existing altitudes of the shore lines clearly proving this. Investigations regarding the position and elevation of the shore lines of the St. Lawrence basin have been continued at intervals since and considerable new data obtained. Very interesting observations have been made on the north side of the two lower great lakes, Ontario and Erie, showing the geomorphism which the region has undergone in the post-glacial or recent stages of the Post-Tertiary. The following notes, deduced from the field work of the last seven years, are preliminary to a more detailed discussion of the results.

High-level shore lines of marine origin fronting the St. Lawrence to the north have been traced almost without interruption from the Gulf of St. Lawrence westward along the northern base of the Notre Dame Mountains, a distance of 550 miles or more, the altitude of the highest at Gaspe being 240 feet, while as we approach the international boundary east of Lake Champlain it is 865 feet. Another series extends along the north side of the St. Lawrence and Ottawa rivers at approximately the same altitude, reaching 900 feet north of the city of Ottawa. Besides the regional upheaval indicated by the shore lines observed on both sides of the valley, differential vertical movements of a local character have taken place at intervals along these strands since they were at sea level, or in a horizontal attitude; in some places there appears to have been a greater uplift than in others, and such uplift seems occasionally to have been followed by still more local downward movements. On the south side of the valley and in the maritime districts wherever the shore lines rest upon crystalline, or igneous rocks, they were observed to be deformed to a greater extent than elsewhere and raised above the average height. This singular and

* This Journal, April, 1896, vol. i (4th series), pp. 302-308.

† Annual report, Geol. Surv. Can., vol. x, 1897 (new series), pp. 12–54 J.

‡ The term Pleistocene embraces the period beginning with the Post-Tertiary and ending with the Champlain, or with the deposition of the Leda clay and Saxicava sand.

apparently abnormal feature is more particularly noticeable in that portion of the highest shore line which extends along the south side of the valley referred to for a distance of 100 to 120 miles east of the international boundary, where it rests on the northwest flank of the Sutton or Green Mountain range in its extension into Canada. Similar deformations were also observed on the north side of the St. Lawrence and Ottawa valleys, more especially of the latter. On both sides of the St. Lawrence marine plain, however, the shore lines become considerably broken up before approaching the Archean rocks to the west.

In the region of the Great Lakes high-level shore lines were observed and described many years ago by Logan, Chapman, Fleming, R. Bell, Spencer and others, while more recently Lawson and Bell have explored and traced them along the north and northwest side of Lake Superior, where they bounded a great body of water to which the name Lake Warren was given. On the north side of Lakes Erie and Ontario four or more of the strands referred to occur. The lowest, which has been named the "Iroquois beach" by Spencer, and was first traced by him, is not horizontal, but has an average descent southwestward of about two feet to a mile. It extends from the Trent river, or from a point north of Belleville, to the head of Lake Ontario. Another lies above it having a similar slope, not however much more than about a foot to the mile, the altitude falling from 775 feet at Myrtle, Grand Trunk railway, to 705 feet in Lambton county. This is probably a part of the so-called Algonquin shore line, which has been traced on the south side of Georgian Bay with such care and described by Mr. A. F. Hunter of Barrie*. The third is a well-defined one which was followed from Trent river to Hyde Park, Middlesex county, a distance of about 200 miles, and is practically horizontal throughout. The altitude is 890–892 feet. The fourth and highest is terrace-like, and may be called a plateau, as it is 1100 feet high in its eastern extension in Durham county, near Pontypool, and 1200 feet near Stratford, Perth county. A depression crosses it east of the Credit river.†

These four Ontario shore lines are of lacustrine origin; but how the waters of the Great Lakes were held up to their level is the great problem. As stated in the opening sentences of this paper, there seems no doubt that the whole of the region of the Great Lakes stood at a lower level than at the present day during the existence of the earliest and largest of these bodies of water—Lake Warren,—that is, at the period when the shore lines now found at an altitude of 1100–1200 feet were

*Summary Report, Geol. Surv. Can. for 1902, pp. 279–302.

†The altitudes were all measured from railway stations and referred to mean sea level. See Summary Report, Geol. Surv. Can., 1902, pp. 272–274.

formed. A great mass of literature bearing on the origin and development of these old water lines and of the lake basins themselves has appeared from time to time in the scientific journals during the last two or three decades, and geologists are by no means in accord as to their origin. In the United States the hypothesis of an ice dam in the St. Lawrence Valley during the latter part of the glacial period is generally accepted, but most of the Canadian geologists are inclined to regard that of an oscillating land barrier to the north and northeast of the Great Lakes as the most probable cause.

In regard to the latter theory it may be stated that there is a belt of granite or Archean rocks about fifty miles wide crossing the St. Lawrence at the Thousand Islands connected with the Adirondacks to the south, and with the great Archean area to the northwest, towards which it widens out as we proceed in that direction. This Archæan neck, as it is sometimes called, seems to have been an oscillating axis in the Post-Tertiary period and up to the present day. As, however, the shore lines of the St. Lawrence Valley and Great Lakes are of post-glacial age, it is only its later Pleistocene and recent history with which we are concerned. At this stage the St. Lawrence Valley below the Thousand Islands and the region of the Great Lakes would be at a lower level than at present, as already stated, and the axis referred to must have been higher. This valley would then be a gulf or arm of the larger Gulf of St. Lawrence and the barrier described would form, on its east side, the shore of the Champlain sea, and on its west a great fresh-water lake, or series of lakes, would be held in, the floor of which is now represented to some extent in Southwestern Ontario by plains and terraces 1100–1200 feet above the sea. These water levels, as already pointed out, can be seen at Stratford and on the watershed between Ontario and Simcoe Lakes, also at corresponding heights in the Lake Superior basin, as described by Bell and Lawson.*

The sequence of events which occurred in the St. Lawrence Valley and basin of the Great Lakes brought about by the changes of level which followed may be thus summarized:—

1. A subsidence of the Archean rocks immediately to the north of the Great Lakes with correlative upward movements to the east and to the west. These changes of level seem to have reached a stationary position, temporarily, when in the lake region the 890–892 feet shore line was formed; and in the St. Lawrence Valley, the 890–895 feet terrace.

2. Another subsidence of the axis referred to then followed,

* The Geological History of Lake Superior; Trans. Can. Institute, Memorial volume, 1849–99, by Dr. R. Bell; Sketch of the Coastal Topography of the North Side of Lake Superior, by Dr. A. C. Lawson.

with apparently the same correlative uplifts to the east and to the west, when on reaching the level of the 775–705 feet shore line in the basin of the Great Lakes there was another halt. This shore line is also recorded in the St. Lawrence Valley, though now shown at various altitudes and in various positions. The two higher strands north of Ontario and Erie Lakes then became slightly tilted towards the northeast.

3. Another downward movement of the central axis following, the formation of the "Iroquois beach" took place on the one hand, and corresponding shore lines at low levels in the St. Lawrence Valley on the other. The upper shore lines, both on the east and west of the central oscillating axis, would now slope towards it, though they have since returned nearly to a horizontal attitude.

4. Following was a period of moderate oscillations along the axis referred to, some downward and some upward, the forces producing them having apparently been largely spent, or having approached an equilibrium. These changes resulted in the breaking down of the strands along the margin of the oscillating zone on both sides, and in a considerable amount of denudation taking place. Lake Ontario was probably lower than at present, perhaps nearly or quite at sea level.

5. A slow series of reverse movements then set in which consisted mainly in a rise of the crystalline axis. This has continued to the present day with correlative subsidences in the areas formerly uplifted to the east and west. These changes are evidenced by the fact that the "Iroquois beach," which was, just previous to this period, in a horizontal attitude, is now tilted to the southwest, and similar movements, though in a reverse direction, have taken place in the St. Lawrence Valley, the raised shore lines there now sloping eastward longitudinally. What the amount of the uplift at the Thousand Islands has been since, it is difficult to say. Judging from the present levels of the "Iroquois beach" it would seem as if the rise must be fully 200 feet; but the hinge or axis of the movement may not have been at the eastern end of the existing beach.

The oscillatory movements of the barrier referred to would seem to have been limited and slow, nevertheless they affected, it appears, not only the granite axis, but a wide tract of country on either side, beyond which, as shown, complementary movements occurred. Even when the axis was at its lowest level, however, Lake Ontario must have been somewhat higher than the sea or gulf; for there is evidence of an eastward flow of the lake waters at this stage. Stratified beds of gravel and sand showing deposition in waters flowing in the direction indicated were found upon the granite axis at altitudes of 800

to 850 feet, or 300 to 400 feet higher than similar deposits on either side; and yellow sands and gravels containing concretions, common in the basins of Ontario and Erie lakes, were observed in the marine area to the east overlying the Saxicava sands and Leda clay, which must also have been carried down by an overflow of the lake waters.

The discussion of the causes of these oscillatory and complementary movements will have to be reserved for the present. It may be remarked, however, that it is only reasonable to assume that in the folding and compression of the rocks of the Northeast Appalachians along the border of the large Archean area to the north, there must necessarily have been transverse thrusts and uplifts along certain lines of weakness, though most of these have hitherto been supposed to antedate the post-Tertiary period. Three of these apparently crossed the St. Lawrence basin,—one at the Thousand Islands, a second along the line of igneous intrusions crossing the St. Lawrence Valley at Montreal, and a third at Quebec city.

The foregoing explanation of the phenomena is offered tentatively, though the writer has observed all the facts in the field and feels confident that it is to geomorphic changes we shall have to look for a solution of the problems presented in regard to the elevated strands and the origin of the basins of the Great Lakes themselves. The theory, it will be seen, includes only one downward movement with three or four pauses or temporary cessations of the stresses producing them, and one upward movement, still in progress, the latter proved to some extent by observations made by Professor G. K. Gilbert of the United States Geological Survey.* The geomorphism which has taken place outside of the St. Lawrence basin is not considered in this note; it is thought, nevertheless, that the changes there will all harmonize with those outlined in this paper. It seems to the writer that the theory is a more rational one, and more in accordance with observed geological phenomena, than that of glacial dams. The author is convinced that when the history of the great changes of level which have occurred in the region in question during the post-Tertiary period comes to be studied more in detail, geomorphology will be found to constitute an important factor, and along with denudation, enable us to explain the conformation of the surface features without resort to such adventitious and epigene agencies as are sometimes employed.

Ottawa, Canada, June 22d, 1904.

* Recent Earth Movements in the Great Lakes Region, Eighteenth Annual Report, U. S. Geological Survey, 1896–7, part ii, pp. 601–647.

Art. XXIII.—*The Material and Shape of the Rotating Cathode;* by H. E. Medway.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXX.]

In a previous article from this laboratory* a method has been described for the rapid, electrolytic precipitation of metals upon a rotating platinum crucible made to serve as a cathode. In the present paper is given the record of experiments with other and cheaper metals, used in place of the more expensive platinum, as well as cathodes in the form of discs.

Experiments were made with a silver crucible of 50$^{cm^3}$ capacity, carefully cleaned, dried at 100° C., weighed and adjusted to the rubber stopper which serves to hold the crucible and press against its inner wall two platinum strips which make the electrical connection.

Into the electrolytic cell was put an acidulated solution of copper sulphate, standardized by deposition of copper upon the rotating crucible of platinum.

Deposition upon Silver.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·1088	0·1086	−0·0002	2·	6·6	15
(2)	0·1088	0·1090	+0·0002	2·	6·6	15
(3)	0·1088	0·1084	−0·0004	1·5	5·	15
(4)	0·1088	0·1085	−0·0003	2·	6·6	15
(5)	0·1088	0·1080	−0·0008	2·	6·6	15
(6)	0·1041	0·1041	+0·0000	2·	6·6	15
(7)	0·1041	0·1046	+0·0005	2·	6·6	15
(8)	0·1041	0·1039	−0·0002	2·	6·6	15

The results of these experiments would seem to indicate that the use of a silver crucible leaves little to be desired so far as accuracy is concerned.

To remove the copper from the crucible, the deposit was rubbed off as much as possible and the rest dissolved in a strong boiling solution of hydrochloric acid, and this was accomplished with but trifling loss of silver, as is shown in the statement below:

	I.	II.
Weight of crucible before treatment ..	36·0089	36·0062
Weight of crucible after treatment	36·0062	36·0041
Loss of silver	0·0027	0·0021

* Gooch and Medway: This Journal, xv, 320, 1903.

Since the crucible should in any event be weighed before each determination, such small loss does not seriously affect the availability of the silver crucible as a substitute for platinum.

Similar experiments were made with a nickel crucible of 50^{cm^3} capacity, under a procedure exactly the same as that described, with the results as recorded.

Deposition upon Nickel.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. Min.
(1)	0·1041	0·1028	−0·0013	1·5	5·	15
(2)	0·1041	0·1054	+0·0013	2·	6·6	12
(3)	0·1041	0·1036	−0·0005	2·	6·6	15

These results show that while nickel may be employed as a cathode, too much reliance must not be placed upon results obtained by its use when the greatest exactness is required. Care must also be taken in drying the crucible, since nickel is very easily oxidized with a consequent increase in weight. The deposit of copper was removed from the crucible with nitric acid, with considerable loss of nickel, as the following will show:

	I.	II.	III.
Weight of nickel crucible before treatment	17·6478	17·6161	17·6091
Weight of nickel crucible after treatment	17·6161	17·6091	17·5932
Loss of nickel	0·0317	0·0070	0·0059

So it appears that, while the silver crucible may with some economy and without sacrifice of accuracy be substituted for the platinum crucible used as a rotating cathode in the electrolytic determination of copper, the ease with which the crucible of nickel is attacked, both during the analytical process and in the subsequent removal of the deposit, is a bar to the use of that metal for the rotating cathode.

Shepherd* recommends the use of the ordinary disc anode of platinum as the rotating cathode, in place of the platinum crucible, while a stiff platinum wire, carried in semi-circular conformity to the edge of the disc cathode, serves as the anode.

According to my experience with this form and adjustment of apparatus, the deposits obtained are not so adherent as might be desired and tend to crumble away from the edge of the disc; and the same thing is true of discs of copper and silver. The probable reason for failure to obtain an adherent

*Jour. Phys. Chem., vii, 508, 1903.

deposit is that the edge of the disc, being nearer the anode, receives more current and larger deposit of copper than the central portions, with the consequence that the deposit upon the edge, built out and fragile, tends to break off under the rapid rotation of the disc. To remedy this defect, I have used for an anode a strip of platinum extending across the cell under and parallel to the rotating disc, so that the current may be equalized all over the disc. With the apparatus arranged in this manner, the following very good results were obtained in the precipitation of copper.

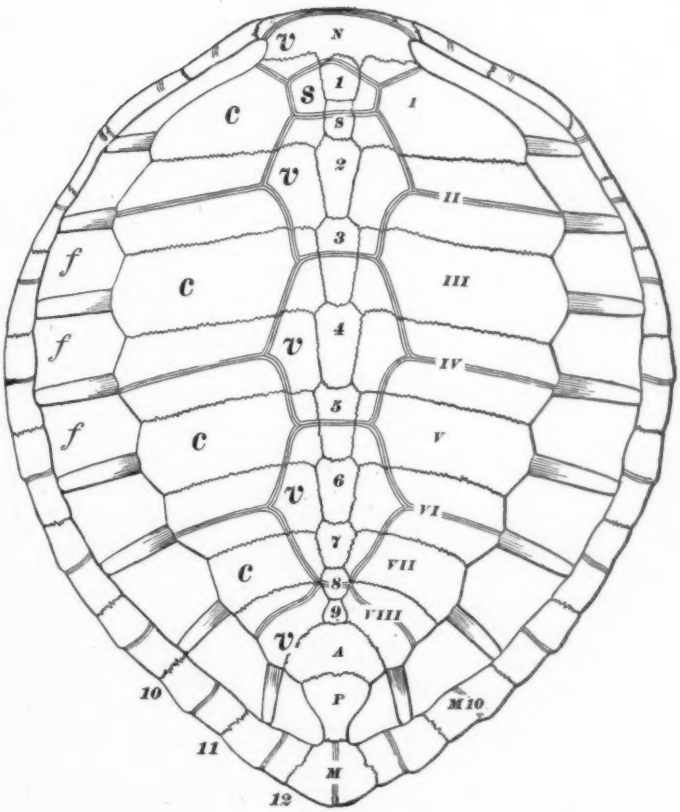
Deposition upon the Platinum Disc.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. Amp.	N. D. 100.	Time. min.
(1)	0·0670	0·0672	+0·0002	2·	12	15
(2)	0·0670	0·0668	−0·0002	2·	12	15
(3)	0·0670	0·0666	−0·0004	2·	12	15
(4)	0·0670	0·0671	+0·0001	2·5	15	15
(5)	0·0670	0·0670	±0·0000	2·	12	15

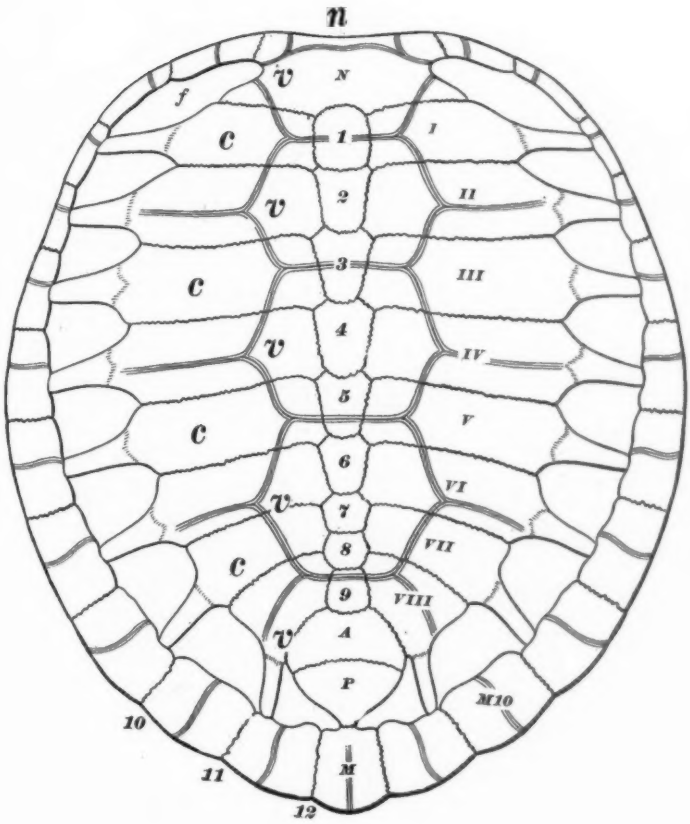
The attempt to substitute aluminum for platinum, though the former metal has been recommended by Hough,* as material to receive the deposit, was not successful, owing probably to the film of aluminum oxide always present. Various measures were taken to remove this film—e. g., the aluminum was treated with hydrochloric acid and quickly transferred to the solution, a few drops of hydrofluoric acid added before the current was passed—but all to no avail, the copper falling off as fast as deposited.

From my experience, it seems that the disc is inferior to the crucible for use as a rotating cathode. Not only does the disc fail to hold the deposited copper as well as the crucible, but there are difficulties of manipulation which render the drying and weighing of the deposit upon the disc comparatively inexact.

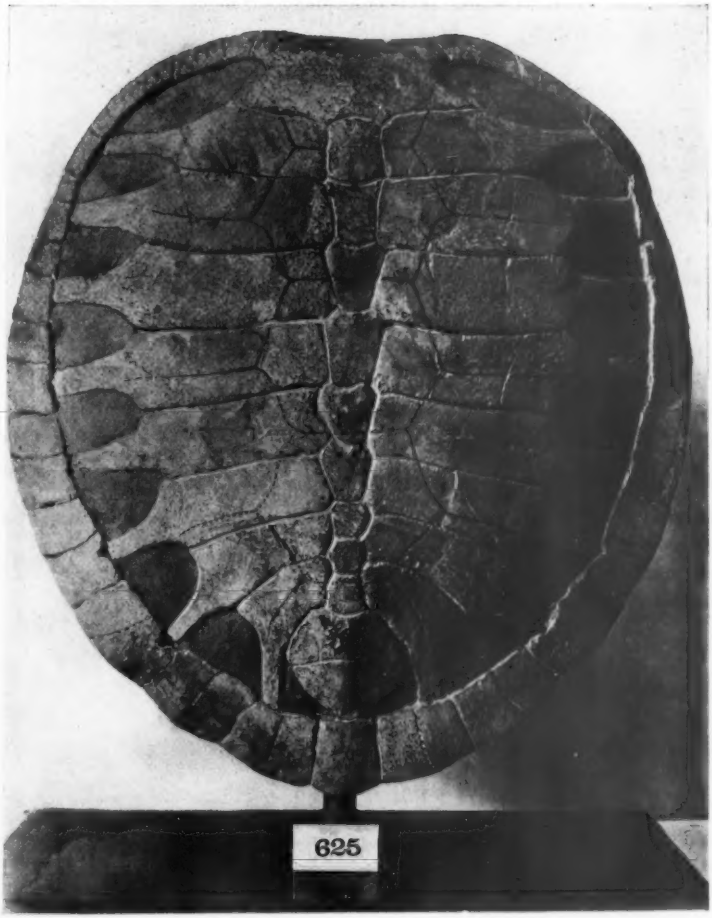
* Jour. Am. Chem. Soc., xx, 302.



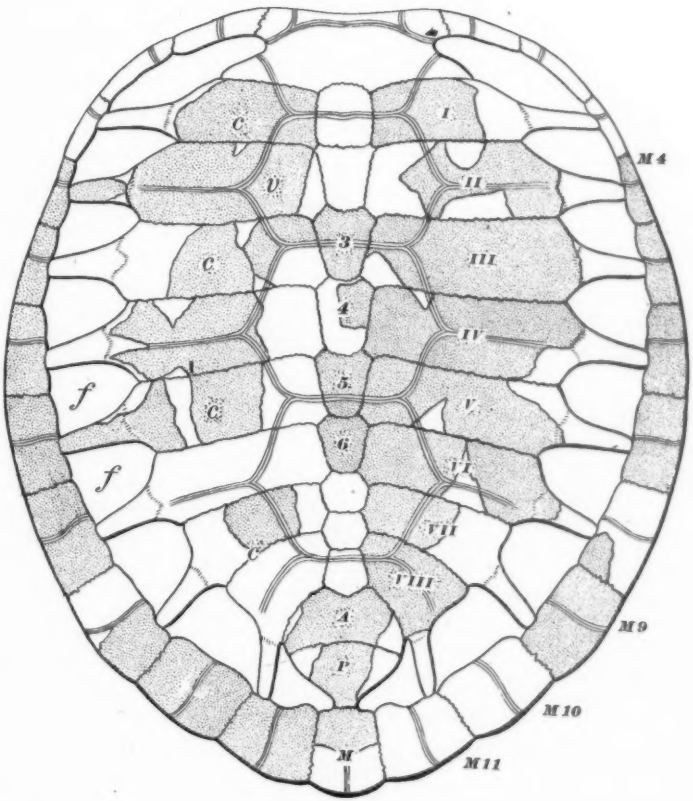
Carapace of *Chelone mydas* L. (var. or sp. nov.) Southern Atlantic coast of the United States. A young specimen $\times \frac{1}{4}$. Free borders in smooth, sutures in zigzag, and boundaries of the horn-shields in triple line.



Carapace of *Lytoloma angusta*. × about $\frac{1}{6}$. Drawn from the specimen shown in the following Plate, VII.



Carapace of *Lytoloma angusta* from the Upper Cretaceous Greensand of Barnsboro, Gloucester Co., New Jersey, as partly restored and mounted in the Yale Museum.—See Plate VIII.
Actual length of Carapace about 58 cm.



Carapace of *Lytoloma angusta*. × about $\frac{1}{3}$. Diagrammatic figure. The stippled surfaces show the parts of the original specimen as recovered in a disarticulated and more or less broken condition. See Plates VI and VII.

ART. XXIV.—*Structure of the Upper Cretaceous Turtles of New Jersey: Lytoloma;** by G. R. WIELAND. (With Plates V–VIII.)

IN 1865 Leidy described as *Chelone sopita* certain chelonian marginals from the Upper Cretaceous or Greensand of Tinton Falls, Monmouth county, and several others from Mullica Hill, Gloucester county, New Jersey. One of these specimens, including three left marginals and part of a fourth, was figured as the type.†

In 1870 Cope established his genus *Lytoloma*, at the same time making a not very clear reference of Leidy's *Chelone sopita* to both *Propleura* and *Lytoloma*.‡ The type species of the latter genus, *L. angusta*, as figured, is seen to consist of a single marginal and fragmentary lower jaw with a remarkably long symphysis. Bearing in mind, however, the closely associated manner in which the numerous forms from the New Jersey Greensand occur, there is at present no positive proof that this marginal and lower jaw belong to the same individual or even species, although both these possibilities are probable.

The close resemblance of the lower jaw of *Lytoloma* to that of *Chelone crassicostatum* (Owen, 1849)§ was noted by Cope. The latter type consists of a skull and lower jaw articulated in normal position, and is a rarely perfect specimen. It was more completely freed from its matrix,—a hard septarian nodule from the London Clay (Lower Eocene), and further illustrated and described, by Lydekker, in 1889, as *Lytoloma crassicostatum*.‖ Its generic relationship to *L. angusta* of the New Jersey Greensand, and to the lower jaw from the Landenien (inférieur) of Erquellinnes, Belgium, first described by Dollo as *Pachyrynchus*,¶ and later referred to Euclastes,** appears to be unquestioned.

* The first paper of this series, on *Adocus*, *Osteopygis*, and *Propleura*, was published in this Journal, Feb., 1904. The third paper will be on *Agomphus*.

† Cretaceous Reptiles of the United States, Smithsonian Contr. to Knowl., vol. xiv, 1865, pl. xix, fig. 5.

‡ Extinct Batrachia, Reptilia and Aves of North America, 1869, pp. 140, 145; and pl. xi, figs. 1–1b.

§ Fossil Reptilia of the London Clay, Part I. Chelonia, Paleontographical Society, p. 27, pl. xi.

‖ On a skull of the Chelonian genus *Lytoloma*. Proc. Zool. Soc., London, 1889, pls. vi, vii.

¶ Les Cheloniens, Landeniens (Eocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, Juill, 1886.

** With reference to the priority and synonymy of the species here discussed, it is necessary to note that the skull *Euclastes platyops* Cope was first mentioned in 1867; hence *Euclastes* antedates *Lytoloma* two years. Moreover, according to Dollo (Sur le Genre *Euctastes*, Ann. Soc. Geol. du Nord., t. xv, p. 114, Mars, 1888) *Euclastes* includes *Chelone* Owen, 1841; *Lytoloma* Cope, 1871; *Glossochelys* Seeley, 1871; *Puppigerus* Cope, 1871; *Pachyrynchus* Dollo, 1886; *Erquellinesia* Dollo, 1887. But later Boulenger and Lydekker (Geol. Mag., Dec. 3, vol. iv, p. 270, 1887), pointed out that *Euclastes* is preoccupied; thus the later name *Lytoloma* becomes valid.

It is thus seen that the cranial characters of *Lytoloma angusta* Cope are inferentially known and point conclusively to a position in the Cheloninæ, although as yet no adequate description of a Lytoloman carapace from the Greensand of New Jersey has been given. It is therefore of distinct interest to find that the Yale specimen No. 625 proves to be a fairly complete carapace, with marginals so distinctly like those of *L. angusta* as to indicate their specific identity. Moreover, the rather close relationship to *Propleura*, and the various primitive characters present, add to our knowledge of the early marine forms, and bring us a step nearer to the actual lines of descent of existing marine turtles from littoral forms. While not known to have survived beyond the Eocene, the Lytolomas show by their structure that they were not more than generically removed from the existing genus *Chelone*. Before passing on to the description of the carapace, however, it will, because of the extended synonymy just reviewed, the considerable number of years since the collection of the materials from New Jersey, and the fragmentary condition of many of the specimens, be necessary to note briefly the evidence as to accompanying cranial characters.

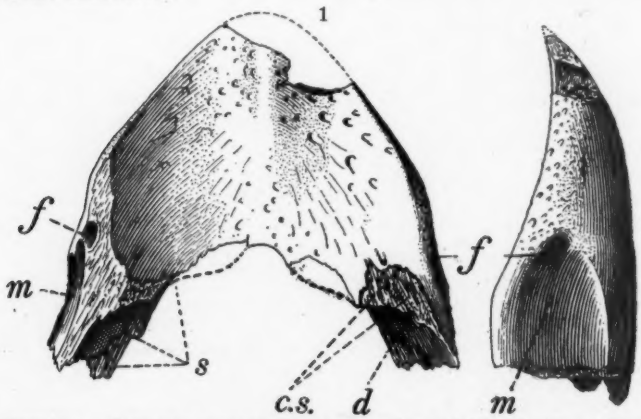


FIGURE 1.—*Lytoloma angusta* Cope. Superior and lateral view of Dentalium. ×½. (Y. S. 913, from Upper Cretaceous Greensand of Hornerstown, New Jersey. *c. s.*, coronoid suture and sutural surface; *s*, splenial suture and sutural surface; *d*, dental foramen (orifice slightly arched over); *f*, nutrition foramen (for mandibular branch of jugular vein—Bojanus); *m*, masseteric fossa (insertion of masseter muscle).

The Lower Jaw.

Evidence of the specific association of lower jaws and marginals of the *Lytoloma angusta* form is not abundant in the Yale collections, though fairly conclusive. A dentalium which is accompanied by a fragmentary but characteristic marginal is

shown in figure 1. Several more or less isolated jaws of the same form attain about double the size of that illustrated.

The relative width of the lower jaw of *Lytoloma* is much greater than in the living Chelonians. Its further peculiarities are mainly to be observed in the dentalium, notable for its remarkably long symphysis and very large pits for the insertion of powerful masseter muscles. These specialized features primarily suggest a *conchifragous habit.** The massive imperforate palatal surface described below also strongly supports the view that these Lytolomas had become littoral conch-eaters, finding their home and an abundant supply of mussels and other "shell fish" on the New Jersey Cretaceous shore lines.

The Cranium.

With the exception of *L.* (Euclastes) *platyops* Cope no further *Lytoloma* crania from the Upper Cretaceous of New Jersey have been figured. The only specimen in the Yale collection referable to the genus is an isolated anterior portion of a skull, which is, however, in a wonderful state of preservation, as shown in the accompanying text—figure 2 (A, B, and C). There is no means of now determining with certainty whether or not this specimen is a *Lytoloma angusta.* It is quite possible that the lower jaw pertaining to it had a somewhat differently shaped coronoid region than that of *L. angusta.* Rather than erect a new species on such slender evidence, it may suffice to refer to this rare and interesting specimen by number when comparing its characters with those of other forms. With *L. platyops* Cope† this comparison is as follows:—

Lytoloma (Euclastes) *platyops* Cope.	*Lytoloma*, Yale specimen No. 913a.
1. "Maxillaries and palatines separated throughout by the prolonged vomer."	1. Maxillaries and palatines *probably* separated throughout by elongate vomer.
2. "Posterior nares opposite palatal front margin of orbits" (? ?).	2. Internal narial opening well back from both the lower (palatal) and the upper (orbital) anterior border of the palatines.
3. "Premaxillary margin projecting beak-like;" alveolar face little concave.	3. As in *L. platyops;* that is, premaxillaries projecting more than in the Chelonidæ, but not forming a projecting and decurved beak as in either *Chelydra* or *Archelon.*
4. "Vomer forming a central ridge."	4. Outer (or palatal) surface of vomer flat anteriorly but raised between the palatines.
5. Floor of nasal meatus perforate for hook of mandible.	5. *Floor of nasal meatus imperforate and very thick.*
6. "Nostrils superior behind the short projecting beak (not borne on a projecting muzzle)."	6. As in *L. Platyops* (not *Bothremys*).

* Dollo, Première Note sur les Cheloniens landeniens (éocène inférieur) de la Belgique, Bull. Musée Roy. d'Hist. Nat. de Belg., t. iv, No. 3, p. 138, 1886.

† Loc. cit., p. 148.

In both the above skulls (borrowing further from the description of *L. platyops*, as given by Cope), the descending portion of the prefrontal is very wide, and equal to the width of the maxillary outside the small lachrymal foramen. Inter-

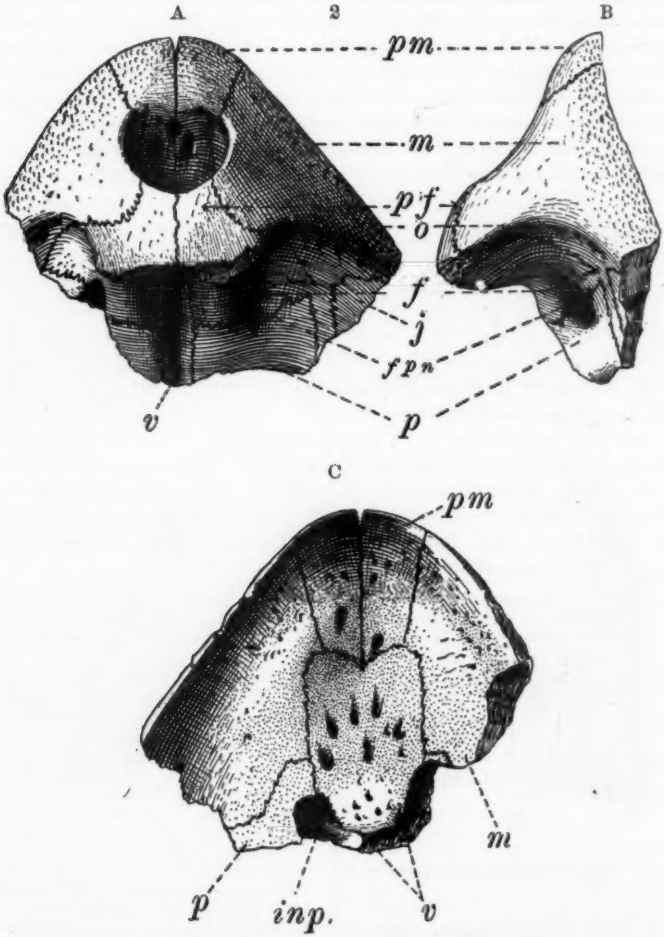


FIGURE 2.—*Lytoloma angusta*? Anterior portion of cranium. ×⅔. Yale specimen 913a. From the Upper Cretaceous of Hornerstown, New Jersey.
A, superior,—B, right lateral,—C, palatal view.—*pm*, premaxillary; *m*, maxillary; *pf*, prefrontal; *o*, anterior border of orbit; *f*, foramen (*alveolare superius*?); *fpn*, *foramen palatino nasal*; *j*, jugal; *p*, palatine; *v*, vomer; *inp*, internal narial passage (the vomero-palatine wall being partly broken away).

nally the columns of the prefrontals converge below nearly to an acute angle and are directed forward, also much backward in *Lytoloma* (Yale specimen No. 913a), thus forming a strong internal base on the vomer. They restrict the nasal meatus, leaving its diameter less than that of the columns.

The internal nares in the present specimen open far back; but the long, broad, and massive vomer is fairly complete, and it is not likely that the palatines closed in behind it to further roof the narial passage. If so, herein may lie a marked difference from the still more specialized Eocene Lytolomas from the London Clay and the Landenien inférieur of Belgium. In describing the skull of *Lytoloma crassicostatum* Owen, Lydekker says: "one of the first points which strikes the observer [on comparison with *Thalassochelys*] is its extreme shortness, the width at the widest part of the temporal arch being exactly equal to the length from the occipital condyle to the muzzle; whereas in the Loggerhead the former diameter is considerably less than the latter, whilst in *Chelone* the difference between the two diameters is still greater. Still more noticeable is the backward position of the posterior nares, which are situated at a point one third the distance from the condyle to the muzzle, as indeed is mentioned in M. Dollo's description of the Belgian specimens. In that description it is, however, stated that the boundary of the posterior nares is formed by the development of the palatal plates from the pterygoids. So far, however, as can be seen from the present specimen, it would appear that this border is really constituted by the palatines, since on either side there seems to be a distinct suture separating the bones forming the border of the posterior nares from the undoubted pterygoids. Looking at the arrangement of the palatines in the Loggerhead, it would seem much more natural that these should be prolonged backwards, rather than that the pterygoids should assume the condition assigned to them by M. Dollo. In either case the vomer is excluded from the posterior nares, but its position anteriorly is not shown in this specimen." (It is obscured by the lower jaw which is in place.)*

The Carapace and Plastron.

The specimen (Yale Catalogue, No. 625) on which the following description is mainly based was received from the West Jersey Marl Company, May 1, 1869. It is from the old, long unworked marl pit, one and one-half miles east of the village of Barnsboro, Gloucester county, New Jersey. Willows, holly, pine, etc., now grow scatteringly over this area of former excavation some thirty acres in extent, which has yielded so many other interesting fossils, among them the remarkably fine carapace and plastron *Osteopygis Gibbi*.

* Lydekker, loc. cit.

The recovered portions of the present specimen, shown in detail by the stippled areas in Plate VIII, consist of (*a*) the third, fifth and sixth neurals; (*b*) the antero- and postero-pygal; (*c*) the pleuralia of the right side less the free-rib tips, but with the inner or neural borders of all but the second distinct; (*d*) the first to the fifth pleurals inclusive of the left side, the free-rib tips of the second and fifth being present, also a fragment of the seventh pleural, as indicated by its form and the postero-lateral furrow of the fourth vertebral horn-shield which crosses it; (*e*) the fourth to the seventh inclusive, and the ninth marginals of the right side, and the fourth to the eleventh marginals inclusive of the left side, with the anterior half of the pygal marginal. There are also some fragments of the accompanying plastron, which, although too incomplete to permit the exact restoration of any of the plastral elements, indicate a plastral form even more reduced than, but otherwise much like that seen in *Osteopygis* and *Propleura*.

With the exceptions mentioned, all parts of the carapace, as far as recovered, are uncrushed and but little broken. As sent to the museum, they were dissociated, but the sutures are well preserved and almost without exception interlock in their normal position, so that it is possible to determine these elements, as well as the general form of the carapace. The fortunate presence of the third neural, with both the adjoining third pleurals as well as two rib tips of the left side, leaves no doubt as to the width of the carapace. Moreover, the borders of the missing second, fourth, seventh, eighth, and ninth neurals are indicated exactly, and those of the first neural approximately. The anterior sutural border of the first left pleural being complete, there can be little doubt but that the nuchal had approximately the outline indicated in Plates VI–VIII. The length of the missing three anterior marginals can only be inferred, but must be nearly that shown in outline.

With regard to the general form of the marginals and of the posterior neurals in the present genus, and in *Osteopygis* and *Propleura*, figures 3–6 in the text afford data for exact comparison. Taken in conjunction with the facts already given, they require little further description. It may only be noted that the specimen represented in figure 5 shows a diminution of the posterior neurals more marked than that in *Osteopygis Gibbi*, while the condition in *Propleura*, figure 6, is more like that of the present form.

As indicated in Plates VI and VII, the horn-shield furrows are all distinct and rather broad. The carapace is of sub-orbicular outline, being broadest across the posterior end of the fifth neural. In this respect it is somewhat intermediate between cordate forms like those of the existing Cheloninæ

and the Osteopyges, which are broadest across the anterior end of the sixth neural. In the present more primitive turtle the cordate form of the Chelonine carapace is beginning to appear, the swinging back of the eighth rib into a pit of the eleventh marginal, and the consequent leaving of the tenth

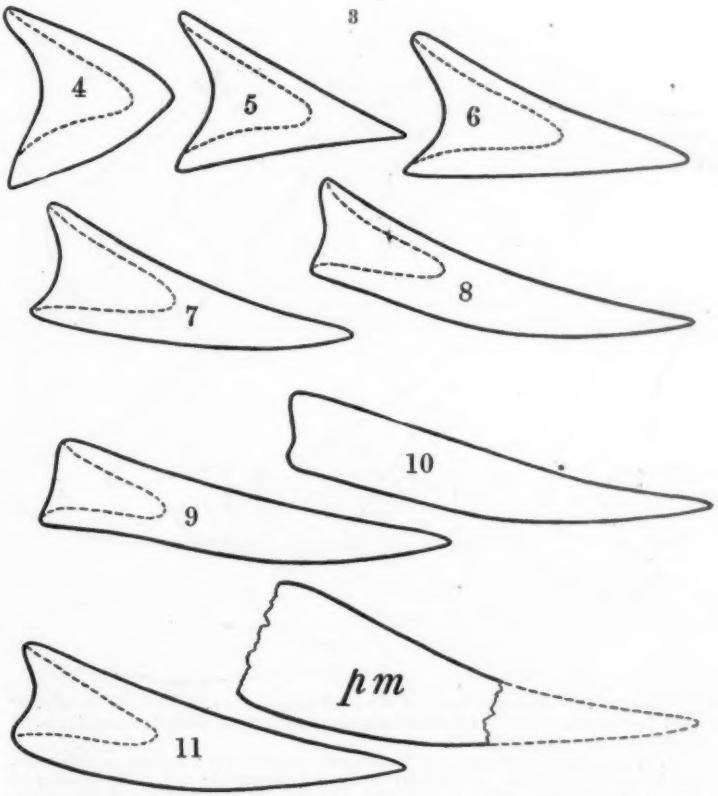


FIGURE 3.—*Lytoloma angusta* Cope (Yale specimen 625). Natural size. Vertical middle transverse section through the 4–11, and pygal (*p m*) marginals. Respective rib pits in dotted outline.

marginal without a supporting rib, as in *Chelone*, having already occurred. Compare plates V and VI. In *Osteopygis Gibbi* the femur is longer than the humerus, and from general comparison it may be argued that in the present species of *Lytoloma* the femur is relatively shorter than in *Osteopygis*, but not so shortened as in the existing marine turtles. This intermediate development is an important point.

In addition to the fragmentary portions present, the general form of the *plastron* is in part indicated by the marginals. The digitations of the antero-external limb of the hyoplastron projected into several small shallow pits in the lower border of the posterior half of the fourth and the anterior half to three-fourths of the fifth marginals, thus forming a dactylate junction

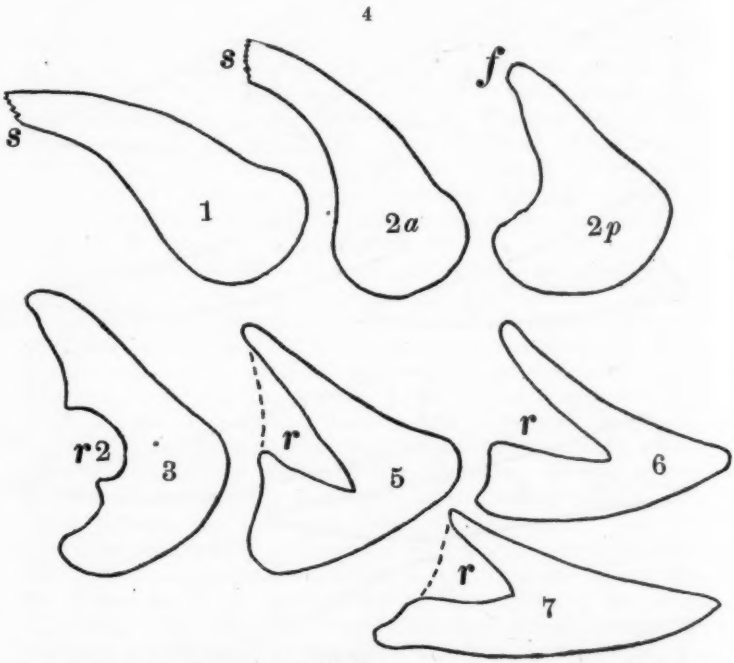


FIGURE 4.—*Propleura borealis* Wieland (type). × ⅔. Vertical, middle, or end transverse sections of marginals for comparison with the marginals of *Lytoloma* shown in figure 3.

1, 3, 5, 6, 7, middle sections numbered respectively; 2*a*, 2*p*, anterior and posterior end outline (or section) of second marginal; *s*, *s*, inner border of first and second marginal (uniting by suture to first pleural and not free as in *Lytoloma*); *f*, free border; *r*2, claw-shaped furrow in third marginal for reception of second rib; *r*, *r*, *r*, rib pits in 5–7 marginals for reception of respective, *i. e.* 3–5 ribs.

6·5 to 8^{cm} in length. This is a distinctly shorter junction than in *Osteopygis*, in which the outer hyoplastral limb extends forward to the second marginal, and is about equal in extent to that seen in *Eretmochelys*. No distinct pits for the reception of the outer digitations of the hypoplastron exist in the fossil at hand. In the Osteopyges, these are present for both limbs of

the plastron, marginals 2 and 8 being deeply pitted for the extreme ends of the hyo- and hypoplastron, respectively, as explained in the description of *O. Gibbi* and *Propleura*. In

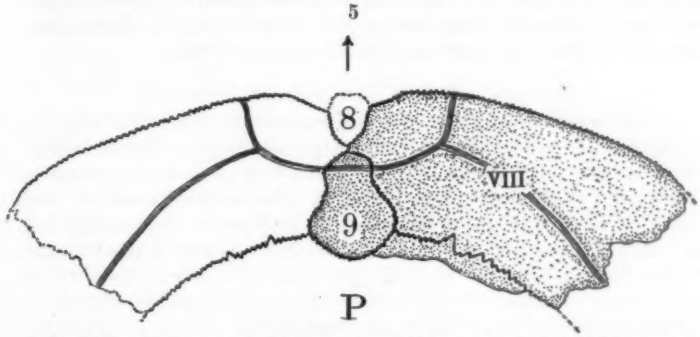


FIGURE 5.—*Osteopygis* sp. (Yale specimen 908). × ½. Right eighth pleural with the ninth neural and a portion of the antero-pygal (P) attached. Horn-shield borders of fourth and fifth vertebralia and fourth costal horn-shields distinct and shown in triple line. (Thickness of neural is ·7 cm.)

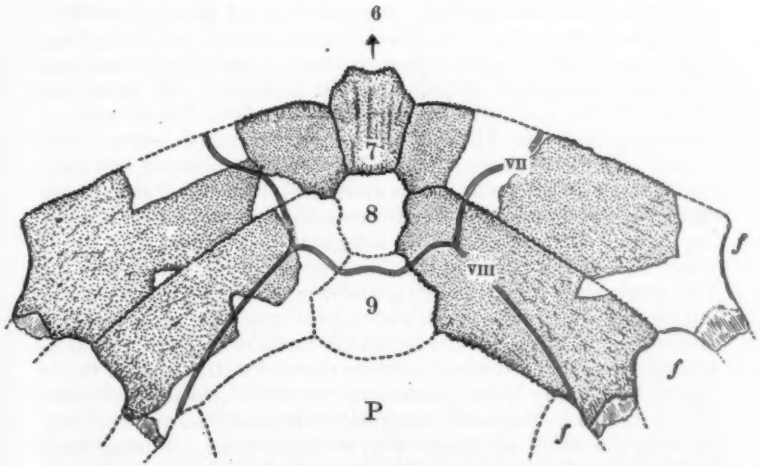


FIGURE 6.—*Propleura* sp. (Yale specimen 559). × ½. Right and left seventh and eighth pleuralia and seventh neural with borders of the fourth and fifth vertebral and the fourth costal horn-shields distinct and shown in triple line. Stippled portions only preserved. 7-9, neuralia; VII, VIII, pleuralia; P, antero-pygal; *f*, *f*, *f*, the three posterior pleuro-marginal fontanelles. (Thickness of pleuralia at sutural edge ·3–·5 cm.) Barnsboro, New Jersey.

the living Cheloninæ, the marginal pits for the plastral digitations are indistinct. Hence, *Lytoloma* is also intermediate in this respect.

Adocus, *Osteopygis*, *Lytoloma*, and *Chelone* thus *virtually* form a series passing from a strong cleido- to a weak dactylosternal plastral junction. The large anterior and posterior plastral foramina and the elongated entoplastron, however, are distinct departures from such a plastron as that of *Adocus*, leading to the plastral form seen in living sea turtles.

Synopsis of the Characters of Lytoloma.

Cranium.—Agreeing in most characters with the existing Cheloninæ, but specialized for a conchifragous habit; short, very broad, with external nares directed as much upward as forward. Vomer large and heavy; internal nares roofed over back of vomer by union of palatines in Eocene species (Lydekker and Dollo), but probably not in New Jersey Upper Cretaceous forms; palatal surface perforate for lower jaw in *L.* (*Euclastes*) *platyops* Cope, heavy and imperforate in *Lytoloma* (Yale specimen No. 913a = *L. angusta?*).

Lower Jaw.—Short and broad, with a very long symphysis, and wide and deep lateral pits for the attachment of heavy masseters.

Carapace.—Suborbicular in outline, with wide and persistent pleuro-marginal fontanelles; composed of 51 bony plates with the boundaries of the (38) horn-shields distinct, the numerical agreement thus being complete in *Osteopygis*, *Propleura*, and *Chelone*. Marginals 11 pairs, narrow anteriorly, but increasing in breadth to the eleventh, which is nearly as broad as long, with outer borders forming an evenly continuous curve to the eighth marginal, beyond which the carapace is more and more emarginate at the ends of the marginals, upper and nether surfaces of equal area, inner surface a shallow rounded furrow; both outer surfaces of fourth marginal nearly flat, with slight concavity of the upper surface and convexity of the lower surface beginning with the fifth and increasing to the eleventh, supported by rib tips only, and upper inner borders bounding the series of large pleuro-marginal fontanelles; rib pits deep and of round to elliptical section, those for the second to the eighth ribs being borne posteriorly on the third to ninth marginals inclusive, the tenth marginal ribless and the eleventh supporting the ninth rib anteriorly, as in *Chelone*. Nuchal large and broad. Neuralia (9) without marked tendency to the suppression of any of the final members of the series, as in *Adocus* and *Osteopygis*. Antero- and postero-pygal as in *Chelone;* surface of the plates smooth, not pitted, and as in the living Chelonians.

Horn-shields.—(38 in number) agreeing numerically with those of *Chelone*. Vertebralia broader than long.

Plastron.—Much as in *Osteopygis*, but with a narrower

bridge (as indicated by fragmentary portions accompanying Yale specimen No. 625, and by marginals 4 and 5).

Limbs.—Little known; humerus and femur thalassoid, and of nearly equal development.

Habitat.—Infralittoral. *Habit.*—Conchifragous.

Range.—Upper Cretaceous and Lower Eocene of Europe and America.

*Systematic Position of Lytoloma and of Osteopygis.**

Where shall we place *Lytoloma*, which in common with *Osteopygis* and *Propleura* has a reduced and somewhat *Chelydra*- or *Staurotypus*-like plastron, and a distinctly *Chelone*-like carapace? It is my belief, based on certain somewhat fragmentary fossils which it is proposed to illustrate later, that in the New Jersey Upper Cretaceous there were already present forms more nearly related to *Chelone* than is *Lytoloma*, although as Dollo well suggests such are far rarer than has been assumed. Second, the free tenth marginal of *Lytoloma* indicates that the swinging back of the ninth rib (or eighth and ninth ribs), thus leaving the ninth or tenth marginal, as the case may be, without rib-support, took place early, and was correlated with the shortening of the femur and the development of heavy front flippers. Third, it appears that *Osteopygis* and *Propleura* belong to a side line, with long and still chelic femora, which never accomplished the rib change just mentioned and did not survive; and fourth, *Lytoloma* originally sprung from this side line. If so, the latter genus developed by parallelism a carapace which, with the skull (that of *Osteopygis* being yet unknown) and the thalassoid humerus, brings it so near to *Chelone* as to make necessary the inclusion of both these genera in the same subfamily.

Having settled this point, the question remains as to whether the two genetic groups containing *Osteopygis*, *Propleura*, and *Lytoloma* on the one hand, and the living members of the Cheloninæ and their more direct ancestors in the other, shall be included in the same subfamily. *Osteopygis*, the most primitive of all the forms in question, is removed from *Chelone* by its less modified limb structure, with all or nearly all the claws present; by its less reduced marginals, consecutively rib-

* In my first paper on the Upper Cretaceous Turtles of New Jersey (this Journal, vol. xvii, Feb., 1904), the opinion was tentatively expressed that *Osteopygis* and *Propleura* might best be separated in a distinct family, namely Cope's Propleuridæ, but the utmost degree of separation any one might suggest, now that *Lytoloma* has been more closely considered, would be as a subfamily,—the Propleurinæ. The position now assigned to these forms is virtually that given them in a provisional classification of marine turtles, proposed earlier (this Journal, vol. xiv, p. 108, 1902), and to which I shall as yet adhere, although recognizing with Dollo the great difficulty, if not impracticability, of satisfactorily dividing the Cheloniidæ into subfamilies in the present imperfect state of our knowledge of the group.

supported; by the absence of pleuro-marginal fontanelles and the nether articular process of the nuchal, and finally by its mere *Chelydra*-like pelvis and earlier type of plastron. Doubtless there are also cranial differences. There is, therefore, between *Osteopygis* and *Chelone*, when considered alone, a very distinct structural interim such as might well characterize two subfamilies. *Lytoloma*, however, is so exactly intermediate that taken with other forms, existing and extinct, there exists a nearly continuous morphological series, passing by simple generic or even lesser stages from the most specialized existing Cheloninæ back to *Osteopygis*. In fact the greatest hiatus remaining unbridged appears to be the ribless ninth or tenth marginal, as seen in *Lytoloma* and existing forms. I am at a loss to surmise if this condition was due to a slowly effected change, or was suddenly developed after the appearance of pleuro-marginal fontanelles in the early line, giving rise to the two genetic groups mentioned. In either case it must have been, as already hinted, correlated with femoral shortening and the development of strong front flippers, and is scarcely to be considered as of more than generic value. If a separation into two subfamilies were made, it would have to be based mainly on this feature, as furnishing the only sharp distinction.

The final conclusion must be that *Osteopygis* and *Propleura* can be placed in a separate subfamily, the Propleurinæ, on genetic grounds, but that further discovery may bring them very near if not into the Cheloninæ. Moreover, as has been seen, these forms, though not apparently forming a closed series, permit the statement that *Osteopygis* was no more than generically separated from some strongly web-footed littoral turtle, which was the true ancestor of the existing Cheloninæ.

The facts given in the present and preceding papers on the Upper Cretaceous turtles of New Jersey, as well as in my paper on *Toxochelys*, indicate the manner in which the marine turtles have been derived from generalized land forms, together with their line of descent. Aside from the carpal and tarsal changes involved and as yet but meagerly illustrated by fossil forms, the most interesting future discoveries will be the ancestral, littoral, and fluviatile Osteopygoid tortoises.

Measurements of Lytoloma.

(A) The dentalium of *Lytoloma angusta* (Yale specimen No. 913.) Uncrushed.

Width (measured from outer extremities of the coronoids)	7·5 cm
Distance (on median line) of hook from anterior ends of the coronoids	4·7
Length of median symphysis	4·2
Greatest vertical depth of median symphysis	1·1

(B) Anterior portion of the skull of *Lytoloma* sp. (Yale specimen No. 913 a = *L. angusta* ?.) Uncrushed.

Length of palatal surface of vomer	3·3
Width " " "	2·0
Length of palatal surface of premaxillary	2·7
Greatest width of palatal surface of premaxillary	1·0
Greatest thickness of vomeral partition between the nares	1·1

(C) The carapace of *Lytoloma angusta.* (Elements uncrushed and disarticulated. Yale specimen No. 625.)

Length (estimated to within one or two centimeters)	58·
Breadth (greatest, as measured across anterior end of fifth neural)	53·

(1) *Bony Plates.*

	(a) Exact length on outer edge of carapace.	(b) Width along groove of horn-shields.	(c) Greatest thickness.
Nuchal	--	--	--
1st marginal	--	--	--
2d "	--	--	--
3d "	--	--	--
4th "	5·5	2·5	2·4
5th "	7·2	3 6	2·3
6th "	7·2	4·3	2·2
7th "	8·	4·8	1·8
8th "	8·	5·6	1·5
9th "	8·2	6·	1·3
10th "	7·5	6·	1·3
11th "	7·8	5·5	1·5
Pygal "	4·7	(5·5)	1·8

	Length on median line.	Greatest width.	Thickness.
Nuchal	----	----	--
1st neural	(5·0)	(4·0)	--
2d "	(5·0)	(5·0)	--
3d "	4·4	4·4	·6
4th "	(5·5)	(4·2)	--
5th "	4·1	4·1	·7
6th "	4·1	3·4	·7
7th "	(3·1)	(3·3)	--
8th "	(3·0)	(2·7)	--
9th "	(3·5)	(3·0)	--
Antero-pygal	3·7	8·0	1·1
Postero-pygal	6·0	(8·0)	--
Marginalo- "	6·0	4·7	1·8

	Length over curvature.	Median width.
1st pleural	20·	5·
2d "	24·	6·
3d "	25·	5·5
4th "	25·5	5·3
5th "	24·5	5·
6th "	22·	5·
7th "	19·	5·5
8th "	15·	5·

(The large pleuro-marginal fontanelles are approximately one-third the length of the pleurals which respectively bound them.)

(2) *Horn-shields.*

	Length on median line of carapace.	Greatest breadth.
Nuchal	----	----
1st vertebral	----	11·
2d "	10·	14·5
3d "	11·	13·5
4th "	11·4	15·
5th "	----	----

Length of fifth–eleventh marginal horn-shields, respectively, measured along outer border of carapace :—6·5, 7·5, 8·0, 8·5, 8·0, 8·0, 7·5.

LETTERING OF PLATES V–VIII.

(a) Bone Plates :—*N*, Nuchal ; *1–9*, Neuralia ; *A*, Antero-, *P*, Postero-, *M*, Marginal-Pygal ; *I–VIII*, Pleuralia ; *M9–M11*, 9th–11th Marginals ; *s* (in Plate V), Supernumerary neural.

(b) Horn Shields :—*n*, Nuchal ; *v*, *v*, *v*, *v*, *v*, 1st–5th Vertebralia ; *c*, *c*, *c*, *c*, 1st–4th Costalia ; *S* (in Plate V), Supernumerary vertebral ; 10–12, Marginalia ; *f*, *f*, *f*, Pleuro-marginal fontanelles.

Yale University Museum,
New Haven, Conn.

ART. XXV.—*The root-structure of North American terrestrial Orchideæ;* by THEO. HOLM. (With figures in the text.)

FEW orders have offered a larger number of interesting data in the various phases of the life-history of plants than the *Orchideæ*. By their manifold structures, readily perceivable among their various biological types, they have for years attracted considerable attention and furnished ample material to writers on morphological and anatomical botany. It is quite natural that the epiphytic species have received a more general treatment than the terrestrial, on account of their unquestionable prominence in floral and vegetative characters, besides that their cultivation being less difficult has made them more accessible to study than the others. Among the terrestrial species very few have been studied from a general point of view except old-world species, but several of these have, nevertheless, served as the very basis of such magnificent contributions to science as those of Irmisch. While, thus, our native, terrestrial *Orchideæ* are very little known from a morphological and anatomical point of view, the following notes on their root-structure are offered as a small contribution to the knowledge of these interesting plants, with the intention to add some further observations in a subsequent paper, which we have made upon the other organs.

As a general result of these observations we might state here, that it seems to be a rule that a tuberous rhizome is only provided with slender roots as is the case with *Arethusa*, *Calypso*, *Bletia*, *Tipularia*, *Aplectrum*, etc., while species with slender rhizome may possess tuberous roots, as for instance: *Orchis spectabilis*, *Platanthera*, *Spiranthes*, etc., or the roots may be equally slender, as in *Cypripedium*, *Goodyera* and certain species of *Pogonia: verticillata*, *ophioglossoides* and *divaricata*.—We might, also, call attention to the fact, that the development of such varied structures of roots and rhizomes does not seem to be dependent upon any special nature of environment; on the contrary, species with tuberous rhizomes may occur in open bogs as well as in deep, shaded woods; and species with tuberous or slender roots may be found in bogs, ravines, in dry fields or in clearings in thickets. In this particular respect the plants themselves seem to possess a very pronounced individuality, and are difficult to classify as meso-, hydro- or xero-phytes. It appears even to be rather uncertain whether some of these species are to be considered as auto-phytes or hemisapro-phytes.—And when we consider the general structure of the roots alone, it seems quite

impossible to offer any satisfactory explanation as to certain facts, for instance, the presence of a velamen in *Tipularia discolor*, and its absence in *Aplectrum*, although the nature of the surroundings, the substrate even, is the same in both, and they both are terrestrial. In *Bletia verecunda*, on the other hand, the development of a similar velamen may be explained as an inherited character, since other species of the genus are epiphytic. A similar approach to the epiphytic root-type as demonstrated by certain species of *Spiranthes* is, also, very puzzling, inasmuch as this genus does not, otherwise, exhibit any analogies in common with epiphytes.

From these data, it may be readily appreciated that the *Orchideæ* are not to be classified in anything like natural sequence based upon root-structure alone, and we have thought, therefore, that it would be the most convenient to treat the different types of roots by themselves, and regardless of the natural affinities of the genera or species in question. In this way a general idea of the root-structure may be obtained with less difficulty.

The following types may be distinguished as characteristic of the terrestrial species:

A. Roots slender with the leptome and hadrome located in one central-cylinder.

B. Roots tuberous with the leptome and hadrome located in one central-cylinder.

C. Roots tuberous with several cylinders of leptome and hadrome.

Of these types the first, A, represents several cases of deviation from the ordinary root-structure by the presence of a velamen for instance (*Tipularia*, *Bletia*), by a peculiar striate thickening of cortex (*Liparis*), and by the development of a true pith (*Calypso*, *Goodyera*, *Habenaria*, etc.). The second type, B, is especially characteristic by reason of its large dimensions, due to numerous layers of cells in cortex and pith, while the third, C, as already indicated, possesses several mestome-cylinders.

Type A.

Cypripedium acaule Ait., *C. pubescens* Willd., *C. guttatum* Swtz., *C. montanum* Dougl., *C. fasciculatum* Kellogg, *C. Californicum* Gray and *C. arietinum* R. Br.

In the genus *Cypripedium* the root-structure comes nearest that of a normal root and may be described as follows: The epidermis is thin-walled in all the species enumerated above, with the exception of *C. guttatum*, in which the outer cell-wall is slightly thickened; root-hairs are usually abundant. A thin-walled hypoderm of one layer is, also, noticeable, but is

moderately thickened in *C. guttatum*. The cortical parenchyma consists of from 6 to 8 strata with large deposits of starch; it is quite compact, but thin-walled, except in *C. pubescens*, where the cell-walls are thickened and porose. Endodermis is mostly thickened as an U-endodermis outside the leptome, but it is otherwise thin-walled, and the following deviations may be mentioned. In *C. acaule*, *guttatum* and *arietinum* 3 to 4 thick-walled cells were observed outside the leptome, while 6 in *C. Californicum;* in *C. pubescens* and *C. montanum* 2 to 4 cells were thickened like an O-endodermis outside the leptome, while in *C. fasciculatum* the entire endodermis was found to be thin-walled throughout. The pericambium is only represented by a single continuous layer in all the species; it is thin-walled except in *C. arietinum*. The rays of the hadrome are very broad and meet in the center; they average from 5 to 10, 8 to 10 being the characteristic of *C. montanum;* a thick-walled pith forms a small central group in *C. Californicum*, but not in the others. The leptome is well developed in large groups alternating with the rays of the hadrome.

None of the roots were found to be contractile, and hyphæ were noticed in: *C. pubescens* (epidermis, hypoderm and cortex), *C. fasciculatum* (cortex) and *C. guttatum* (endodermis and pericambium).

Epipactis gigantea Dougl.

Epidermis, hypoderm and cortex are all thin-walled, and much starch is deposited in the cortical parenchyma. The endodermis is thin-walled throughout with the Casparyan spots plainly visible and with contents of starch; the pericambium forms a closed ring around the leptome and hadrome; it consists of only one layer, the cells of which are prominently thickened outside the leptome, but otherwise thin-walled. Five broad rays of hadrome extend to the center of the cylinder and alternate with large, roundish groups of leptome. No hyphæ were observed.

Listera cordata R. Br. and *L. australis* Lindl.

The structure of the roots of these two species is almost identical, and the difference depends merely upon the relative development of hairs, which are very numerous and long in the former species, but quite scarce in the latter; moreover, the leptome constitutes groups of quite large dimensions in *L. cordata*, but not in the other species; otherwise the structure is identical. Epidermis and hypoderm are thin-walled, and the cortex which occupies the greater portion of the root is composed of about 5 layers, the cells of which are very large, thin-walled and filled with starch; the intercellular spaces are

narrow. Endodermis is moderately thickened all around, while the pericambium is thin-walled and continuous in *L. cordata*. Five narrow rays of hadrome meet in the center with five relatively wide vessels, and alternate with roundish groups of leptome; the conjunctive tissue is thin-walled and is only to be observed between the vessels, but not in the center of the cylinder. Hyphæ were observed in epidermis, hypoderm and cortex of *L. cordata*, but not in *L. australis*.

Pogonia ophioglossoides Nutt., *P. verticillata* Nutt. and *P. divaricata* R. Br.*

Epidermis is thin-walled and densely covered with hairs in *P. ophioglossoides* and *divaricata*, but less so in the third species. The hypoderm is thin-walled in *P. ophioglossoides*, slightly thickened in the others. The cortex is composed of 6 to 9 layers of thin-walled cells; it is quite open in *P. ophioglossoides*, but very compact in the other species. Starch was only found in *P. divaricata*. Endodermis is thin-walled throughout in *P. ophioglossoides* and *P. divaricata*, but in *P. verticillata* there is one thick-walled cell outside each group of leptome. The thin-walled pericambium is continuous in *P. ophioglossoides*, but is irregularly interrupted by the protohadrome vessels in the two other species. The leptome represents quite large and roundish groups alternating with narrow rays of hadrome; 5 rays were observed in *P. ophioglossoides*, 6 in *P. divaricata* and 8 in the third species; the hadrome extends to the center of the cylinder in *P. ophioglossoides*, but not in the other species. Hyphæ were found in the hypoderm and cortex of all three species.

Calopogon pulchellus R. Br., *C. multiflorus* Lindl. and *C. parviflorus* Lindl.

The root-structure is very uniform in these species and resembles that of *Pogonia*, especially *P. ophioglossoides*. Epidermis and hypoderm are thin-walled in all three species, and the cortex, which, also, is thin-walled, consists of about 8 layers with narrow intercellular spaces; no starch was observed in the cortex. The endodermis is thin-walled throughout, with the spots plainly visible. In the central-cylinder we find a thin-walled pericambium in the two first species, but one moderately thickened in *C. parviflorus;* it is continuous in *C. pulchellus*, but we were unable to trace the exact location of the protohadrome vessels in the other species, whether these had broken through the pericambium or not. Five, and quite broad, hadromatic rays were observed in *C. pulchellus* and *C. parviflorus*, but only three in *C. multiflorus;* the innermost vessels are relatively wide and border on a small, but very distinct, cen-

* Compare this Journal, vol. ix, 1900, p. 13.

tral group of slightly thickened parenchyma. The leptome occurs as small, roundish groups in transverse section. Hyphæ were found in the cortex of *C. multiflorus* and *C. pulchellus*, but none in the third species.

In the following genera of this same type the roots are quite slender, but possess in contradistinction to those described in the preceding, a well developed central parenchyma, which evidently represents a true pith, homologous with the pith of the stem.

Habenaria repens Nutt.

This species is a native of very damp places, and when growing in water the very long roots produce root-shoots. A thin-walled epidermis with few hairs and a hypoderm surround a cortex of about 20 layers of thin-walled cells, of which the outermost 4 constitute a compact and persisting tissue, while the interior 16 are traversed by numerous lacunes from the very wide intercellular spaces; only a little starch, but many bundles of raphides were observed in the cortex, besides hyphæ in the peripheral strata. The cortical parenchyma is, thus, very open, and in several roots, in the entire length of these, a well defined duct was furthermore observed, surrounded by a sheath of very small, thin-walled cells; neither liquid or solid contents were observed in this duct, and its function may evidently be for osmotic exchange of gases.

The endodermis and the continuous pericambium are both thin-walled. In regard to the hadrome and leptome, the former does not occur in rays, but merely as small groups, from 6 to 15, each consisting of a few, 2 to 5, mostly wide vessels, which to a more or less extent alternate with the equally small groups of leptome. The arrangement of the hadrome in proportion to the leptome is somewhat irregular, and we observed several cases where the leptome was really located in front of the hadrome, thus imitating the radial position of these same elements in the stem; in other cases the vessels were on each side surrounded by a group of leptome with the two proto-leptome cells very distinct (fig. 1), as in mestome-bundles of the hadrocentric type, and this position was frequently observed in *H. repens*. The larger portion of the central cylinder consists of a thin-walled pith with deposits of starch.

Arethusa bulbosa L.

The epidermis is thin-walled and densely covered with long hairs; there is, also, an hypoderm, but not easily distinguishable from the cortex. The latter consists of about 6 compact layers with many hyphæ, but without starch. Endodermis and the continuous pericambium are both thin-walled and surround

6 short, but broad groups of rather narrow vessels, alternating with a corresponding number of small groups of leptome, while a pith occupies the greater inner portion of the central-cylinder.

Calypso borealis Salisb.

The structure of the root is almost identical with that of the preceding, and the only differences observed were as follows: the hypoderm is very distinct and the cell-walls are slightly thickened; the cortical parenchyma is a little broader and quite open, the intercellular spaces being relatively wide; the hadrome occurs only as small, 3 to 6, groups of vessels, alternating with the leptome and separated from the center by a large mass of thin-walled pith.

Goodyera pubescens R. Br., *repens* R. Br., *Menziesii* Lindl. and *tesselatum* Lodd.

In respect to the root-structure these species resemble each other very much, and we find in these the same delicate structure of the various tissues, as described above as characteristic of *Arethusa* and *Calypso*. The roots are very hairy, the epidermis, the hypoderm, the cortex, the endodermis and the continuous pericambium are all thin-walled; of these, the cortex consists of about 6 layers in *G. repens* and *tesselatum*, of 8 in *G. pubescens*, and of about 12 in *G. Menziesii;* it is quite compact in all the species except in *G. tesselatum*, in which the intercellular spaces are much wider than in the other species. The hadrome and leptome constitute small groups, when viewed in transverse sections, the former with 4 to 8 vessels in each group, widely separated from the center of the cylinder by a large, starch-bearing and thin-walled pith. The number of hadromatic groups is somewhat variable within the species examined; thus 4 were observed to be characteristic of *G. repens*, 5 of *G. tesselatum* and 6 of the other species. No hyphæ were found in the internal tissues of *G. repens* or *G. tesselatum*, but in the cortex of the others.

Chloræa Austinæ Gray.*

Although the roots of this plant are relatively strong, much more so than in any of the other *Orchideæ* described above, the structure does not reveal any very pronounced mechanical

* The statement by Mr. MacDougal (Bull. Torrey Club 26: 528, 1899) that "this plant is to be added to the list of chlorophylless plants furnished with stomata" is not correct, since we have observed the presence of chlorophyll-grains in the ovary; the guard-cells of the stomata as well as the adjoining epidermis-cells are well supplied with chlorophyll. The description and the figures furnished by this author (l. c.) are altogether very inexact.

equipment. The only tissues which exhibit some thickening are the endodermis and the large, central parenchyma; of these the former is, however, only thick-walled just outside the leptome, and only moderately so. The pith is not thickened very much either, but it occupies such a prominent part, that it necessarily contributes a great deal to the toughness of the root. But the other tissues are thin-walled, and the cortex is composed of 15 compact layers, densely filled with starch and some hyphæ. The pericambium is continuous and surrounds 6 broad rays of hadrome with rather narrow vessels, arranged very regularly in alternation with the large groups of leptome, and border on the very prominent, central pith.

Aplectrum hyemale Nutt.

The densely hairy epidermis, the hypoderm and cortex are all thin-walled, and the last of these consists of about 9 layers with narrow intercellular spaces; no starch or hyphæ were observed, but bundles of raphides. The endodermis and the continuous pericambium are, also, thin-walled and surround 9 broad rays of hadrome, alternating with large, roundish groups of leptome with a central mass of thin-walled pith.

Liparis liliifolia Rich.

The very slender roots show a very feeble structure since all the tissues from epidermis to pith are of a very delicate texture. The epidermis bears many long hairs; the hypoderm is well differentiated from epidermis and cortex by the cells being somewhat stretched radially and almost regularly pentagonal. The cortex consists of about 8 layers and contains a few hyphæ, but no starch; it seems characteristic of certain species of the genus that some of the cells of the cortex exhibit the same spiral thickening of the wall as is well known from the roots of epiphytic genera, a fact that has already been mentioned by Irmisch.* The endodermis is very thin-walled and shows the spots very plainly; the pericambium is continuous and surrounds 12 small groups of hadrome, each with a few vessels, and a corresponding number of small groups of leptome, while a large pith occupies the inner portion of the central-cylinder.

Tipularia discolor Nutt.

As stated above, the roots of this plant show the remarkable structure of possessing a velamen of 3 to 4 layers inside a thin-walled, very hairy epidermis. However this velamen differs from that of the epiphytic *Orchideæ* by lacking the character-

* Beiträge zur Biologie und Morphologie der Orchideen, Leipzig, 1853, p. 34.

istic spiral or simply striate thickening of the cell-walls; otherwise the structure is identical. There, is, furthermore, an exodermis of exactly the same structure as we know from the epiphytic genera. The cortical parenchyma is thin-walled and consists of about 8 layers of roundish cells with narrow intercellular spaces; many hyphæ, but no starch, was observed in this tissue. The endodermis and the continuous pericambium are both thin-walled and surround 5 short rays of hadrome, alternating with 5 small groups of leptome; a pith occupies the inner portion of the central-cylinder.

Bletia verecunda Sw.

In several respects the root-structure of *Bletia* agrees with that of *Tipularia*, but some, and indeed quite important, deviations were noticed. These consist in the more typical development of velamen, the cell-walls of which exhibit the characteristic fine and spiral thickening peculiar to this tissue; moreover by the presence of a double pericambium, which is moderately thickened and to the same extent as the hadrome, thus the position of the proto-hadrome vessels in proportion to the pericambium could not be made out satisfactorily. The hadrome forms 8 short and broad rays alternating with large, roundish groups of leptome, inside of which there is a large, thin-walled pith with intercellular spaces of quite considerable width.

These roots, described above, belong to the first type, all being relatively slender and possessing only one, central-cylinder. In several respects they agree with the second type, in which, however, the dimensions of the roots have increased to such an extent as to deserve the term "tuberous" on account of the much broader zones of the cortex and pith, besides by the larger number of rays or better "groups" of hadrome and leptome.

Type B.

Spiranthes gracilis Big., *S. simplex* Gray, *S. præcox* Wats., *S. Romanzoffiana* Cham., *S. cernua* Rich., *S. cinnabarina* Hemsl. and *S. Asagræi* Schaff.

Even when the roots are quite numerous, as in the last two species, they, nevertheless, retain the same swollen aspect as when they are but few in number or single, as in *S. simplex*. The internal structure is, also, very uniform in these species, and not very different from those described above, but pertaining to other genera.

Common to these species of *Spiranthes* is a thin-walled epidermis with many hairs, besides a hypoderm of one layer, the cells of which are smaller than those of the adjoining cortex.

And as already described by Irmisch (l. c.) as characteristic of the European *S. autumnalis* Rich., the cells of epidermis show the same spiral thickening as we find in the velamen of the epiphytic genera, besides that a similar thickening of the cell-wall is, also, to be observed in the hypoderm of *S. cinnabarina* and *Asagræi*. The cortex is thin-walled and the cells of the innermost layers are very often stretched radially; the number of layers varies somewhat, but is usually about 15, and the contents consist mainly of starch, except in the last two species, where only hyphæ were observed; it seems altogether as if the function of these fleshy roots of *Spiranthes* is to store starch and not water, although the nature of the habitat might suggest that water-reservoirs would be needed. In *S. simplex* and *S. præcox* no hyphæ were observed in any of the tissues, but in the other species the roots proved to be real *mycorhizæ*. As to the innermost layer of the cortex, the endodermis, this seems to be invariably thin-walled in the species examined and shows the Casparyan spots very plainly. The pericambium is represented by only one layer; it is very irregularly interrupted by the proto-hadrome vessels in *S. gracilis*, *S. simplex* and *S. Romanzoffiana*, but in certain roots of the last species it occurred, also, as a continuous ring, the proto-hadrome being located inside. In *S. præcox* the pericambium was found to be continuous near the base of the root, but interrupted near the apex of same. The rays of the hadrome, from 12 to about 20, are very short in all the species and contain but a few vessels, alternating with similarly very small groups of leptome, while the greater portion of the central-cylinder is occupied by a large mass of thin-walled parenchyma, a true pith.

Type C.

The roots of this type are more or less tuberous and contain several cylinders of leptome and hadrome.

Orchis spectabilis L.

If we examine the tuberous root below the hibernating bud, we notice the following structure. Epidermis is thin-walled and there are many root-hairs. Underneath the epidermis is a thin-walled cortex of about 8 layers containing starch and hyphæ, and which borders on 2 mestome-cylinders separated from each other by a few layers of parenchyma, which shows the same structure and contents (starch) as the peripheral cortex. Each mestome-cylinder is surrounded by a thin-walled endodermis, inside of which is a pericambium, which is broken by the proto-hadrome vessels in several places. The hadrome constitutes about 12 irregular and very short rays, which alter-

nate with a corresponding number of leptomatic groups, while a broad pith occupies the inner portion of the cylinder.

The same structure is to be observed in the slender roots of the same rhizome, with the only exception that these contain only one, central mestome-cylinder, the elements of which correspond well with those of the tuberous root, there being about 15 short, hadromatic rays and small groups of leptome surrounding a large, central pith.

Platanthera.

In North America the genus is exceedingly well represented, and occurs with several very distinct types, distinct not only in respect to their flowers, but also in regard to their vegetative organs. The slender, creeping rhizome of *P. rotundifolia* Lindl. is provided with several slender roots, the structure of which is so near that of *P. obtusata* Lindl., that they may be treated together. But in all the other species of the genus examined, the roots, especially the one beneath the hibernating bud, are more or less tuberous, and exhibit a structure that is nearly identical with that of the other secondary, but more slender, roots of the same rhizome.

P. rotundifolia Lindl. and *P. obtusata* Lindl.

Characteristic of the roots of these species is the sparingly hairy epidermis and the lack of any well defined hypoderm. The cortex is thin-walled in both, quite compact in *P. obtusata*, but rather open and not so broad in the other. Large deposits of starch besides hyphæ were noticed in *P. obtusata*, but only hyphæ in *P. rotundifolia*. Two mestome-cylinders of equal diameter are imbedded in the cortex near the center of the root in *P. obtusata*, while there are two large and one much smaller in the other. These mestome-cylinders are, thus, separated from each other by some strata of parenchyma, which may be properly defined as pertaining to the cortex, with which it agrees in regard to structure. Each of these mestome-cylinders has a thin-walled endodermis and pericambium, the latter being continuous in *P. obtusata*. The rays of hadrome (3 in *P. obtusata*, 1 to 5 in *P. rotundifolia*) are very short and consist of but a few vessels, which, together with small groups of leptome, border inward on a thin-walled pith, which is very prominent in *P. rotundifolia*, but rather inconspicuous in the other species.

P. orbiculata (Torr.) and *P. Hookerii* (Torr.).

Habitually these species are very much alike and very distinct from the other North American species of the genus; their root-structure is somewhat different. This difference,

however, depends merely upon the number and relative size of the mestome-cylinders, there being 4, 2 large and 2 small, in *P. orbiculata*, but 8, and all very small, in the other. Besides this variation as to size, their arrangement is, also, quite distinct, since they are located in one ring in *P. orbiculata*, but in two in the other species. Otherwise the structure is identical; the epidermis, hypoderm, cortex, endodermis and pericambium are all thin-walled, and deposits of starch besides raphides were observed in the cortex of *P. orbiculata*, hyphæ, on the other hand, in *P. Hookerii*. Moreover there are noticed 15 short rays of hadrome in the large cylinders of *P. orbiculata*, but only 5 in those of *P. Hookerii*. A central pith was observed in each of these mestome-cylinders and of both species.

The more slender roots show the same structure as the tuberous, described above, but they contain a correspondingly small number of mestome-cylinders, viz: 3 to 4 in *P. Hookerii*, and only 2 in *P. orbiculata*.

In the remaining species of *Platanthera*, which we have examined: *P. dilatata* (Gray), *hyperborea* (Lindl.), *ciliaris* (R. Br.), *psychodes* (Gray), *cristata* (R. Br.) and *tridentata* (Hook.), the roots show an almost identical structure, since the principal difference observable mainly consists in their relative size, their length, thickness and corresponding number of mestome-cylinders, characters of no great importance when we bear in mind the fact, that the tuberous development of such roots is extremely variable and often depending upon certain conditions of the substrate or upon the individual strength of the specimen.

In beginning with the tuberous roots, the epidermis is quite hairy in some species, but merely papillose in others, for instance *P. ciliaris* and *P. psychodes;* this covering with hairs is especially well marked in specimens from *Sphagnum*-bogs. A hypoderm of a single layer is generally present, but seems to lack *P. dilatata*. The cortex is always thin-walled and contains starch, but the number of layers is very variable even in specimens of the same species; hyphæ were observed in all the species except *P. ciliaris*.

The innermost portion of the root is occupied by a large parenchymatic tissue, which, also, contains starch and which is hardly to be distinguished from the cortex; sphærocrystals were observed in great abundance in *P. ciliaris* and *cristata*. The mestome-cylinders occur, sometimes, in several more or less concentric rings, but are mostly somewhat irregularly scattered, especially when their number is very large, as in the thickest roots of *P. ciliaris*. Their number and relative development is variable, but they contain usually from 1 to 5

rays of hadrome with a corresponding number of leptome-groups (fig. 4). The endodermis and pericambium (End. and P. in fig. 4) are constantly thin-walled, and the latter was found to be continuous in some, but interrupted in others of these small mestome-cylinders within the same tuberous root. A very small, central pith was observed in *P. ciliaris* and *cristata*, but not in the others.

If we compare this structure of the tuberous with the slender roots of these same species, there seems to be no other difference than there being a much smaller number of mestome-cylinders in the latter.

Of the three types of roots observable in our terrestrial *Orchideæ*, the third category emphasizes those in which several mestome-cylinders are present instead of but one, and this peculiarity may be briefly described in connection with the anatomical data, mentioned above. The fact that these tuberous roots contain several, isolated cylinders provided with a special endodermis and pericambium, has given rise to various views regarding their morphological identity: whether the "tubers," as they are frequently called, might represent 1) the basal, swollen part of the bud-axis, 2) a single root, 3) a concrescence of several roots or 4) a concrescence of a stem-portion with leaves and roots. Of these the most generally accepted theory is the one which explains the origin of the tuber as being a concrescence of several roots, very ably discussed by Van Tieghem and others.

But the definition tending to explain the tuber as being the result of a concrescence of a stem-portion with leaves and roots, as proposed by Germain de St. Pierre,* has not been approved by others. Nevertheless, as will be shown in the following pages, this definition does not only seem to be well founded, but is, indeed, the only conceivable one, as far as concerns the tuberous body beneath the hibernating bud in North American *Ophrydeæ;* we may illustrate this by the rhizome of *Platanthera dilatata* (fig. 2). The rhizome of this species is relatively slender and the hibernating bud is prominently removed from the mother shoot by the descending stolon (*St.* in fig. 2); the bud itself (*b*) appears as if it were lateral, since the stolon gradually passes over into the long, tuberous body (*r*) underneath the bud, the so-called "tuber" of most authors. The bud, however, is terminal and its apparently lateral position is due to the growth of the stolon, the direction of which is neither horizontal nor vertical, but simply descending. As may be seen from the figure the basal region of the bud with its rudimentary leaves and young roots is located on the upper, the dorsal, face of the stolon.

* Bull. Soc. Bot. de France, vol. 2, p. 659, 1855.

between the lines 4 and 10. Underneath or better "behind" the bud, as the figure shows, is a cylindrical body between the lines 4 and 10, which cannot possibly be defined as representing a stem (stolon) or a root alone, but appears to be a concrescence of both; the result of our anatomical investigation is in favor of this explanation.

In our figure 2, the dotted lines indicate the places where the most important sections have been laid, and the general structure of the rhizome may be briefly described as follows: At its very base (*st.*) the stolon exhibits a structure like that of a typical rhizome with a distinct central-cylinder, surrounded by an endodermis, and with all the minor characters of a stem-portion. But if we examine a section of this same stolon taken a little further down, by the line 2 for instance, the structure is somewhat different, since we observe there two additional, but very small, mestome-cylinders, which are located underneath the central-cylinder; each of these two mestome-cylinders possess an endodermis and a pericambium (End. and P. in fig. 3) and they represent two roots or at least two primordia of such. By continuing our examination of the same rhizome, we observe in section 3 not less than five small mestome-cylinders besides the central, of exactly the same structure as the two described above, and these are very regularly arranged in an arch which is parallel with the lower face of the stolon. At the same time the epidermal structure has become changed, thus the cells on the lower face of the stolon are more or less extended into papillæ and have attained a darker color in contrast to the epidermis of the upper face, which has retained the typical structure of a stem-epidermis. In other words, the stolon has started to become dorsiventral with the development of roots on its ventral face, accompanied by the characteristic epidermal structure.

In following the structure further down to section 4, the large cylinder, formerly central, has become moved nearer the dorsal face of the stolon, and the number of small mestome-cylinders has increased to ten, arranged in two arches parallel with and located near the ventral face. The distinction in regard to the epidermal structure is still more pronounced in this section, and the dorsal epidermis occupies a zone that is much narrower than the ventral. A gradual increase in the number of mestome-cylinders takes place further down, and thirteen were noticed in the sections taken by the lines 5 and 6; furthermore, by 6, the large mestome-cylinder of the stolon is not only still nearer the dorsal face than we observed before, but its pith has become reduced quite considerably in width. And in regard to the bud, the outermost leaf shows here (at 6) a distinct swelling, caused by a cavity at its base. The broad-

est part of the stolon (by 7) contains the bud, and shows, besides, the thirteen small mestome-cylinders, already observed in the section 5, arranged in two arches parallel with the ventral face of the stolon, and with the points of the arches meeting near the central-cylinder of the bud-axis. The large mestome-cylinder is still visible at the line 8 and a little below, but disappears at 9; from here the small cylinders have increased to seventeen, most of which are arranged near the periphery with a few scattered nearer the center. These peripheral mestome-cylinders are quite small and show the same structure as described above; the interior are somewhat larger, but show, nevertheless, an identical structure.

If we now dissect the part of the rhizome located by the line 11, we perceive the structure that has been described so often as characteristic of the "tubers" of *Ophrydeæ:* a large number (23 in this case) of mestome-cylinders, each with a special endodermis and pericambium, and arranged, but not very regularly, in two zones; the distinction between the two epidermal layers (the dorsal and the ventral) has vanished, and the brownish, conical and tuberous body is now covered all around by papillæ and very short root-hairs.

It would thus appear as if at least the upper portion of the tuberous body of the rhizome of *Platanthera dilatata* and the other North American *Ophrydeæ*, which we have examined, is composed of elements pertaining to a stolon, a bud and some roots, instead of being simply a root, a concrescence of several roots or finally a swollen bud-axis. But in offering our support to this explanation, pronounced so many years ago by the French botanist, we are well aware of the difficulty which confronts any investigator who deals with organs that remain in their primordial stage and which are not known to occur otherwise, as the supposed secondary roots of *Ophrydeæ.*

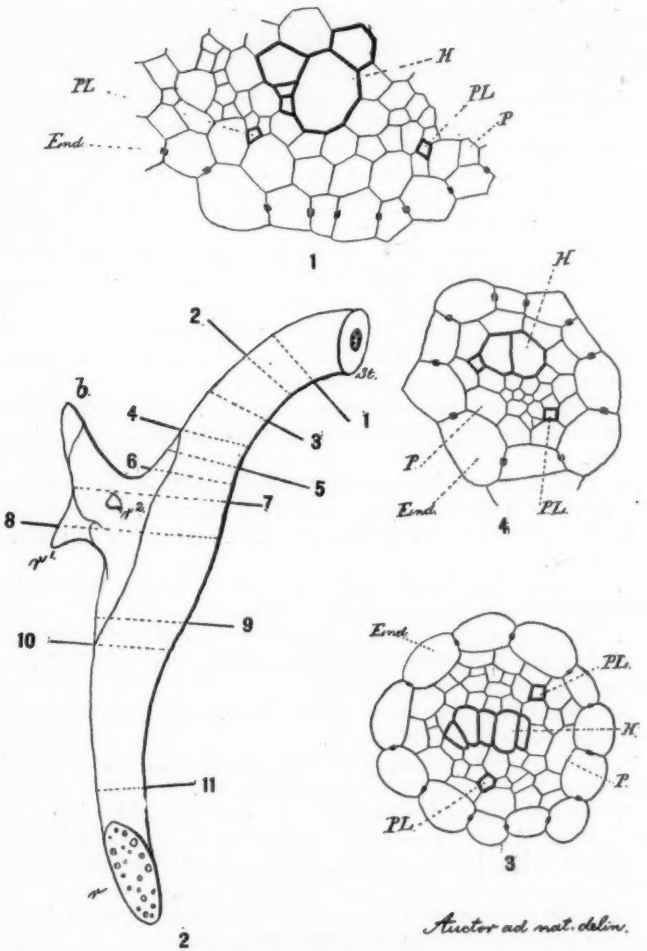
If we had only succeeded in detecting some distinctions in the cortical parenchyma of the stolon, when the supposed roots make their first appearance, so as to be enabled to discriminate between the cortex of the stolon and that of the roots, then there would have been more substantial proof in explaining this organ as a concrescence of roots and stem. But the only distinction which we have noticed depends upon the variation expressed in the epidermal structure, the constant dorsiventrality of the stolon from the first appearance of the secondary roots, and the structure of the small mestome-cylinders being identical with more slender roots of the same species. Of course the word "concrescence" is somewhat misapplied in this particular instance, since these secondary roots have never been observed to be free, not even at the youngest stage of the stolon or of the bud. But otherwise our definition of the

"tuberous body" may from a morphological viewpoint be justifiable, when we compare the rhizome, and especially the arrangement of the roots, with that of other terrestrial *Orchideæ* in which all the roots are free, slender and with only one central-cylinder. In *Arethusa*, for instance, the disposition of the roots is such that if they were united or grown together, they would exhibit exactly the same structure as we have shown being the characteristic of the lower portion of the "tuber" in the *Ophrydeæ*. But the habit of these plants is too distinct to allow us even to imagine ourselves, that such union of the roots in *Arethusa* might be possible.

Summary.

1. A velamen and exodermis is developed in the terrestrial *Tipularia discolor* and *Bletia verecunda*.
2. Some cells of the cortical parenchyma in *Liparis liliifolia* show the same spiral thickening as is known from the epiphytic genera.
3. A similar spiral thickening was observed in the epidermis and hypoderm of several species of *Spiranthes*.
4. The pericambium is composed of two layers in *Bletia verecunda*.
5. The pericambium was observed to be continuous in a number of species pertaining to different genera.
6. The pericambium was observed to be continuous or interrupted in the same root of *Orchis*, *Pogonia verticillata*, various species of *Spiranthes*, etc.
7. Sphærocrystals abound in the inner parenchyma of several species of *Platanthera*.
8. All the roots of *Epidendreæ*, *Neottieæ* and *Cypripedieæ* examined possess only one central-cylinder.
9. A true pith and, sometimes, of quite considerable width was observed in *Tipularia*, *Arethusa*, *Calypso*, *Spiranthes*, *Chloræa*, *Goodyera*, *Habenaria*, *Aplectrum*, *Bletia*, *Liparis*, *Calopogon* and *Cypripedium Californicum*.
10. The cortical parenchyma is traversed by wide lacunes and by a special duct in *Habenaria repens*.
11. The upper portion of the so-called "tuber" of the *Ophrydeæ* examined consists of elements pertaining to a stolon, a bud and some roots; the lower part, on the contrary, of roots alone.
12. The roots of our terrestrial *Orchideæ* very often represent *mycorhizæ*, but not all the roots of the same species, nor of the same specimen.

Brookland, D. C., May, 1904.



EXPLANATION OF FIGURES.

FIGURE 1.—Transverse section of the root of *Habenaria repens*, showing a part of the central-cylinder; *End.* = endodermis; *P.* = pericambium; *P. L.* = proto-leptome; *H* = hadrome. ×320.

FIGURE 2.—Part of stolon with bud and roots of *Platanthera dilatata*, magnified. *b* = apex of the bud; r^1 and r^2 = young roots; *r* = the tuberous root; *st.* = base of stolon. The dotted lines indicate the places where the sections have been laid.

FIGURE 3.—Transverse section of one of the two small mestome-cylinders of the stolon; letters as above. ×320.

FIGURE 4.—Transverse section of a mestome-cylinder from the tuberous root; letters as above. ×320. (Figs. 3 and 4 are both of *Platanthera dilatata;* fig. 3 of a specimen from Vermont, fig. 4 of a specimen from Mt. Elbert in Colorado.)

ART. XXVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;* by E. H. SELLARDS.

[Continued from p. 134.]

Etoblattina coriacea sp. nov. Text-figure 29; and Plate I, Figure 11.

Tegmina long, very slender, pointed at the apex, costal border slightly arched, inner border full, very thick; nervation obscure. Subcosta extending to the apex. Cubitus comparatively short, reaching only a little beyond the middle of the wing. Anal area of medium extent; anal veins about ten in number, simple or forked.

The wing is of especial interest, because of its coriaceous texture in which the veins are almost obscured. Only a few terminal branches of the radius and media can be made out. The branches of the subcosta are entirely obscured. A noticeable feature of the wing is the sharp angle made by the anal area.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas. Type in the University of Kansas collection.

Etoblattina Hilliana ? Plate I, Figure 4.

Scudder, Bull. U. S. Geol. Surv., No. 124, 1895, p. 99, pl. viii, fig. 11.

The wing of Figure 4, Plate I, is doubtfully referred to *E. Hilliana.* The subcostal area is broader than in the type, and the media apparently is not so sinuous.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Spiloblattina.

Scudder, Proc. Acad. Nat. Sci. of Philadelphia, p. 35, 1885; Mem. Boston Soc. Nat. Hist., vol. iv, p. 461, 1890.

The genus *Spiloblattina* was proposed by Scudder to include four species of cockroaches from Fairplay, Colorado. The essential characters of the genus are the wide divergence of the radius and media, and especially of the media and cubitus beyond the middle of the wing, and their subsequent convergence enclosing an elongate or ovate area, the "stigma." Associated with these are other well-defined characters, as the thin tegmina marked with light and dark patches, and dark bands accompanying the veins. The relative distribution of the veins and their areas in this genus are practically the same as in some species of *Etoblattina.* Nevertheless, the *Spiloblattina* group of species, with thin variegated front and hind wings, is evidently a natural one, and without doubt merits generic rank. The sterna of *Spiloblattina* appear from some Kansas

specimens to have a shape different from those of *Etoblattina*, being pointed instead of rounded posteriorly. *Spiloblattina* has not been previously recognized in the Coal Measures, the type having come from deposits which are either Triassic or Permian, but an examination of some Coal-Measure forms from new material convinces the writer that the genus is represented in these formations. In describing the cockroaches from Richmond, Ohio, Professor Scudder noted that some of the species approached closely to *Spiloblattina*, remarking that the disposition of the media and cubitus of *Etoblattina ramosa* is "much after the fashion of *Spiloblattina*." A reëxamination of *Etoblattina maledicta*, a closely related species, leads to its reference in the present paper to *Spiloblattina*.

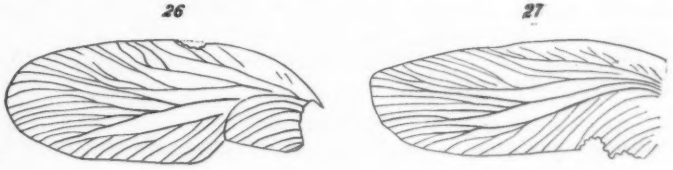
Spiloblattina maledicta. Plate I, Figures 5, 6, and 10; Text-figures 26 and 27.

Etoblattina maledicta Scudder, Bull. U. S. Geol. Surv., No. 124, p. 83, pl. 6, figs. 1–3, 1895.
Etoblattina benedicta Scudder, ibid., p. 84, pl. 5, figs. 14–15.

Tegmina narrow, two and one-half times as long as broad, costal border slightly arched, inner border nearly straight; tegmina broadest at the extremity of the anal area, apex obtuse. Subcostal area narrow, extending a little beyond the middle of the tegmina; branches mostly simple and oblique. The radius reaches nearly to the apex. The first branch is given off at about the extremity of the basal third, sometimes as early as the end of the basal fourth, and is usually twice forked. Three or four other simple or deeply forked branches pass to the border. The media gives off its first branch somewhat beyond the middle. The main vein and its branches fill the apex. The cubitus varies in extent, either reaching well on to the apical margin, its greatest extent being obtained by an outward curve near the termination, or, lacking the curve, ending short of the apical margin. The first five or six branches are straight, mostly simple, and parallel; the others are more oblique, not uniform in number, curved, and sometimes forked. The anal area extends approximately to the end of the basal fourth, is clearly marked off, and has six or seven mostly simple veins. The main veins of the wing originate close together somewhat above the middle of the base. The veins diverge in the central part, enclosing elongate, light-colored areas. The tegmina are delicate and thin, the veins thin, although appearing heavy in places because of the dark-colored bands accompanying them. The alternate light and dark areas give the wing a striking appearance (Figures 5, 6, Plate I). A dark band extends along the costal border obscuring the tips of the

veins. Similar bands accompany the radius, media, and cubitus. Light areas occur in the interspaces between the main veins as well as between some of the branches. Two conspicuous, large, light spots, with irregular boundaries, occur in the apical part of the wing. The agreement with the types of the species from Richmond, Ohio, is very close. The two light spots on the apical part of the wing are not described for the type, probably because the apex was not well preserved.

In the original description of *E. benedicta*, Scudder expressed doubt as to its specific separation from *E. maledicta*. The differences which seemed to distinguish the two forms were the more arched costal border of *E. benedicta*, the less extent of the cubital area, and the approximation in the point of origin of the two radial branches. More than forty tegmina of this species are at hand for comparison. Camera lucida sketches of numerous wings show that, while those with a short cubitus have, as a rule, a more arched border, there is an almost con-



FIGURES 26, 27.—*Spiloblattina maledicta* Scudder, sp.; illustrating the extremes of variation of the species; ×2. Figure 27, typical wing with extended cubitus; Figure 26, form with arched costal border and short cubitus. Originals in University of Kansas Museum.

tinuous series between, with no break sufficient to serve as a specific character. Figures 26 and 27 show the extreme limits in the extent of the cubitus, the two figures corresponding closely to the type figures of the two forms. In one the cubitus falls decidedly short of the apical margin, while in the other it extends by an outward curve and more numerous branches well on to this border. Other specimens show that the cubitus is variable in extent, and individuals can be found presenting a condition so nearly intermediate that a specific separation can hardly be sustained on this character. The third distinction given, the approximation in the point of origin of the first and second radial branches, is not constant. Occasionally a wing is seen having both a long cubitus and a close approximation in the point of origin of the first and second radial branches.

Hind Wings.—The hind wings are thin, and ovate in shape. The costa is submarginal, straight, and simple. The subcostal

area is narrow, has a few superior oblique short branches, and extends to, or beyond the middle. The radius reaches nearly to the apex and gives off about three oblique, widely forked, or simple branches. The media has four or five superior branches which fill the apex. The cubital area is well developed, the branches oblique, straight, parallel, and mostly simple. The anal area is supported by a few simple radiating veins. Eleven hind wings of this species have been obtained, one in direct connection with the tegmina. The hind wing is of even thinner texture than the front, and is also marked by light and dark areas. A dark area extends along the costal border and dark bands accompany some of the veins.

A few specimens preserving parts of the body, especially the abdomen, show evidence of light and dark areas on the body and are, for this reason, provisionally referred to this species (Figure 22). The abdomen is rather slender; the edges of the terga are of moderate extent. The sterna differ from those of *Etoblattina*, being pointed at the posterior angles. Length of the tegmina, 22 to 25^{mm}; width, 8 to 9^{mm}. Hind wings, 16 to 18^{mm} long; 8 or 9^{mm} wide.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Gerablattina.

Scudder, Mem. Bost. Soc. Nat. Hist., vol. iii., p. 97, 1879.

Gerablattina arcuata sp. nov. Text-figure 1; and Figure 7, Plate I.

Tegmina about twice as long as broad, outer border strongly arched, the apex rounded; inner border nearly straight, interrupted by the anal area. Subcosta arched parallel to the inner border, reaching three-fourths the length of the wing, branches numerous, simple, curved, thin, and parallel. The radius is but slightly developed, branches first beyond the middle of the wing, and falls a little short of the apex. The media, like the radius, occupies a comparatively small area, and remains simple until beyond the middle of the wing, its four simple, oblique branches filling the apex. The cubitus is strongly developed and reaches almost to the apex. The first five branches are simple and nearly straight, the others are more oblique, closer, and curved. The anal area is well marked and has about seven simple veins. In texture and general appearance this species presents considerable similarity to *S. maledicta*. The tegmina, however, are much more strongly arched, and the subcosta has a greater development correlated with a reduction in the radius. Length of the tegmina, 24^{mm}; width, 9^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in Kansas Museum.

Schizoblattina gen. nov.

Small cockroaches; veins of the tegmina numerous, much branched, and united in all parts of the wing by frequent, comparatively strong, cross veins. The main vein trunks are free almost or quite to the base, and show a tendency to disappear by dichotomy. Subcostal area broad at the base, strongly developed, with numerous superior branches. Some of the anal veins end on the anal furrow.

Schizoblattina is apparently not closely related to any described genus. *Neorthoblattina albolineata* Scudder, a small species occurring near Fairplay, Colorado, resembles it in its numerous, much branched veins united by straight, comparatively strong, cross veins. The anal veins also present

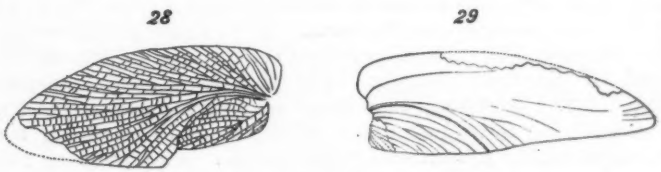


FIGURE 28.—*Schizoblattina multinervia* sp. nov.; × 2.
FIGURE 29.—*Etoblattina coriacea* sp. nov.; × 2. Anal area restored from the obverse side of same specimen. Original in University of Kansas Museum.

the peculiarities of *Schizoblattina*, the first anal giving off several branches which run toward the anal furrow. The other species, including the type of *Neorthoblattina*, have two of the main veins more or less completely amalgamated. That this is also true of *N. albolineata* is not clear from the figure, nor is this point specifically mentioned in the description. It is evident from the peculiar disposition of the anal veins, the occasional cross nervules, and the prolific branching of the veins, that *N. albolineata* is markedly different from the other species of the genus in which it is at present placed, and as far as it is possible to judge from the illustration seems to fall more naturally in *Schizoblattina*.

The geological age of the Fairplay beds, from which *N. albolineata* came, is unsettled, the formation having been referred both to the Triassic and to the Permian.

Schizoblattina multinervia sp. nov. Text-figure 28.

This Journal, vol. xv, pl. vii, fig. 6, April, 1903.

Tegmina small, a little more than twice as long as broad. Costal and inner borders both arched, sloping gradually and equally to the apex, which is placed about the middle of the

wing. Tegmina strong, supported by numerous close branches with frequent, comparatively strong, cross veins in all parts of the wing. Subcostal area broad at the base, triangular, extending a little beyond the middle of the wing. The branches are numerous, once or twice forked, the first arising from near the base and the distal more oblique than the proximal. The radius is clearly distinct from the subcosta. The first branch is given off about the end of the basal fourth of the wing and is two or three times branched. The main vein runs in a sinuous course, reaching the costal border a little short of the apex, giving off three or four oblique, once or twice forked branches. The media is close to, but distinct from, the radius. It dichotomizes first beyond the first branch of the radius, near the end of the basal fourth of the wing. Both branches dichotomize frequently, the numerous divisions filling the distal third of the inner margin and the apex. The cubitus divides early. The branches, dichotomizing two or three times, fill the middle third of the inner margin. The anal area is of moderate extent. The first anal vein gives off five superior branches. The first and second of these, arising close to the base, are once forked, the other three being simple. The first four run toward the anal furrow, the fifth turns down parallel with the furrow and passes to the inner border. A forked inferior branch is also given off from the first anal. The greater part of the area is thus occupied by the first anal and its branches. Three other short curved veins can be seen close to the inner border. Length of tegmina, 17^{mm}; breadth, 7^{mm}.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Type in the writer's collection.

Archoblattina.

Megablattina, Sellards (non Brongniart), this Journal, vol. xv, p. 312, April, 1903.
*Archoblattina**, Sellards, ibid., vol. xv, p. 488, June, 1903.

Large cockroaches; body bulky, abdomen broad and fleshy; pronotum large, longer than broad, approaching a rectangular form, truncated or slightly emarginate in front, emarginate at the sides, broadest and rounded behind; front and hind wings large, overlapping the abdomen.

Archoblattina Beecheri. Text-figures 30, 31, and 32.

Megablattina Beecheri Sellards, this Journal, vol. xv, p. 312, April, 1903, pl. viii.
Mylacridæ sp.? Scudder, Bull. U. S. Geol. Surv., No. 124, p. 55, 1895, pl. ii, fig. 4.
Blattina sp.? ibid., p. 142, pl. x, fig. 16.

Tegmina large, about three times as long as broad, costal border arched only very slightly, inner border nearly straight.

* *αρχων*, prince.

Subcosta curved parallel with the costal border and extending two-thirds the length of the wing, giving off numerous simple or compound branches. Radius forked about one centimeter from the base, and consisting of a few long, nearly parallel branches, which strike the border near, but above, the apex. The media forks first near the middle of the wing; the median

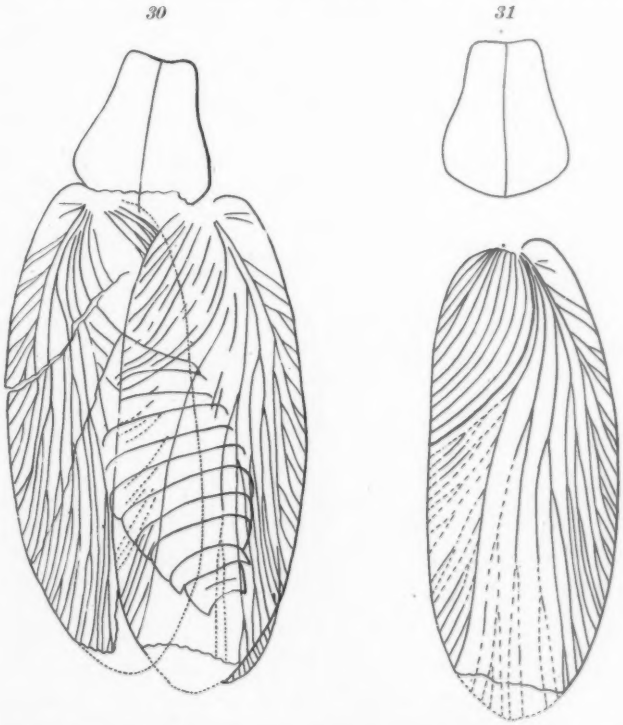


FIGURE 30.—*Archoblattina Beecheri* Sellards; type specimen; dorsal view.
FIGURE 31.—The same; pronotum and wing partly reconstructed.
Original in Yale University Museum.
Both figures are natural size.

area is narrow, consisting of a few long veins running to about the apex. The cubitus, although imperfectly preserved in the specimen at hand, is evidently of great extent, apparently reaching to, or beyond, the inner angle of the wing, and giving off numerous inferior branches. The anal area is of medium extent, strongly marked off by a prominent furrow, and consists of nine or ten simple or forked veins.

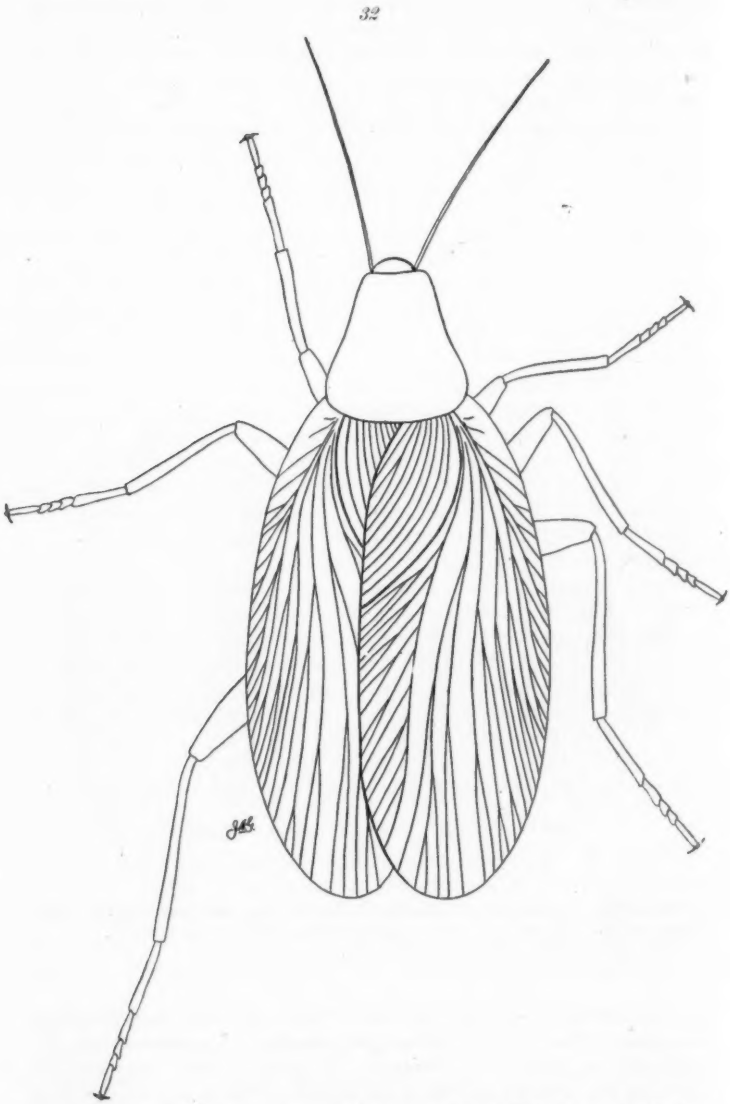


FIGURE 32.—Restoration of *Archoblattina Beecheri* Sellards; natural size.

The most distinctive character of this genus of huge cockroaches is the large, nearly rectangular pronotum, broadest at the base, and with sides and anterior border slightly emarginate. The abdomen is seen indistinctly through the wings; it is large and indicates a bulky body. The length from the front of the pronotum to the tip of the wing is 9^{cm}, making this probably the largest cockroach known. The tips only of the hind wings are seen. Apparently they are of about the same extent as the front wings. The large hind wing from the same locality, described as *Blattina* sp. by Scudder, is here provisionally referred to this species. If this reference is correct, the hind wings are very broad, with much rounded inner border.

The half-tone illustration accompanying the original description of the species was made from the mould of the dorsal surface. The figure given here is taken from the counterpart, in which the outline of the abdomen is more distinct. The two pairs of wings considerably overlap the broad abdomen. The life-size restoration is made from the specimen figured. The antennæ and legs are reconstructed from related genera. The position adopted is based upon an instantaneous photograph taken for this purpose, of the common oriental cockroach, while running. As represented in the restoration the first leg on the left side has just been thrown out in front, the second on the right side is in motion, while the third on the left is just ready to be drawn forward. The other set of three are, for the instant, supporting the weight of the body. It is not known whether the tibiæ of the genus are supplied with spines. These features are, therefore, omitted from the restoration (Figure 32).

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type in the Yale University Museum.

Hind Wings not in connection with Front Wings.

The difficulties of nomenclature met with in the systematic treatment of the nymphs of fossil cockroaches are again encountered in dealing with such detached hind wings as lack sufficient characters to identify them with their respective front wings. Several well-marked types of hind wings, presumably representing at least as many species, have been recognized in the collections studied, three of which can be identified with the front wings. The hind wings of *Spiloblattina maledicta* have been described above in connection with the tegmina of that species. The hind wing of *Promylacris rigida* (Figure 36) is taken from the type specimen (No. 38045, U. S. Nat. Mus.). It is of special interest as revealing the form and

venation of the hind wing of the Mylacridæ. The wing is narrowed at the base, the costal border being nearly straight or a little concave at this point. The inner border although not complete is evidently rounded, and the apex obtuse. The most interesting feature of the wing is the position of the costa, which is some distance from the margin and gives off a thin superior branch. The subcosta is a stronger vein, but has only one offshoot. The radius is more developed; it divides into two nearly equal parts near the base, both of which are compound, the ultimate divisions supplying the border from the termination of the costa to the apex. The media also divides into two compound, nearly equal divisions close to the base, the branches running to the apical border. The cubitus gives off a few inferior branches which curve regularly to the border. Only a small part of the anal area is preserved. The wing just described is the left wing of the specimen. The costa of the right has two thin superior branches. The radius differs in the detail of its branching; the first and second offshoots of the lower division of the main vein are united for a short distance at their base, making a single forked branch instead of two simple branches. Length of the wing, 24 or 25^{mm}; breadth, 11 or 12^{mm}.

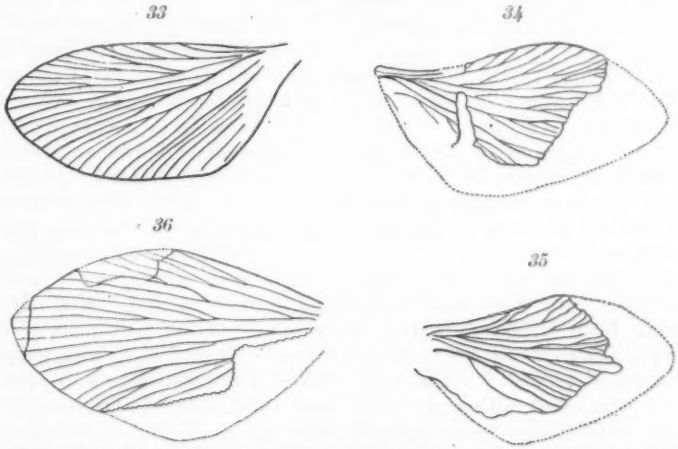
Formation and Locality.—Middle or Lower Coal Measures, Mazon Creek, Illinois.

The type of hind wing most abundant in the Lawrence Shales is that illustrated in Figure 33. There are nine specimens of the species, all conforming closely to a common type. The wings are uniformly ovate. The inner border is full and rounded. The costa is straight, simple, and reaches about one-fourth the length of the wing. The subcostal area is, as usual, in the hind wing, narrow and of slight extent. A few thin superior branches are given off from the main vein beyond the extremity of the costa. The radial area reaches nearly to the apex and has about four forked branches. The median area is large and fills the apex. The cubitus has several very oblique, simple, parallel branches. The few anal veins are parallel and usually simple, longer and more curved than in *Spiloblattina maledicta*. The wings are all of a brownish color. The species doubtless belongs to the genus *Etoblattina*, as the wings are of the ovate type, with full inner borders, thus resembling other species of that genus. Length of wing, 18 to 20^{mm}; width, 9 to 11^{mm}.

Formation and Locality.—Upper Coal Measures, Lawrence, Kansas.

Another species, the generic reference of which is doubtful, is represented by three specimens. The wing is contracted at the base and has an unusually narrow attachment. The costal

border near the base is quite concave, and the wing otherwise shows evidence of a specialized condition. The subcosta, radius, and media are united for some distance from the base. The first to separate is the media, which occupies a comparatively narrow area, branching first about the middle of the wing, its divisions running to the apex. The radius then separates from the subcosta 5 or 6^{mm} from the base, and reaches almost to the apex. The subcosta has only a few thin superior branches. The cubitus has the typical, very oblique, mostly simple veins. The anal area is long and has a few curved, forked, and rather loosely placed veins. Length, about 17^{mm}; width, 9 or 10^{mm}. Figures 34 and 35.



FIGURES 33–36.—Hind wings. Figure 33, *Etoblattina* sp.; Figures 34 and 35, undetermined; Figure 36, *Promylacris rigida*, from the type specimen; all twice natural size. Originals of Figures 33 and 35 in University of Kansas Museum; of Figure 36 in the National Museum.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas. Types in the University of Kansas collection.

General Considerations.

The cockroaches have proved themselves a remarkably persistent type. They are known to range in time from the Middle Carboniferous to the present, and doubtless took their origin somewhat earlier. The Carboniferous representatives, as described above, were in many respects much like their modern descendants. The body had, as Scudder has well said, essentially the same shape. The legs indicate the same habit

of locomotion. The pronotum was as characteristic a feature of the Carboniferous as of the recent cockroaches, and formed quite as secure a protection for the small inflexed head. The front wing had a similar arched form, and the anal area was as well defined. Nevertheless, a closer inspection of the successive types reveals the fact that the group has by no means remained stationary throughout its long existence, but, like other organisms, is subject to the laws of advance and specialization. As will be gathered from what has preceded, the most marked changes from paleozoic to recent times have been in the structure of the framework of the front and hind wings, as well as in the abdomen and the ovipositors, and are thus in accordance with the general rule of change from the simple to the more complex, or from the generalized to the more specialized condition. In the front wings the tendency has been toward a reduction of the main veins by fusion of one or more of them. The main veins of both wings have approached more closely to the costal border. These changes have been accompanied by a less uniform development of the main veins and their branching systems. The hind wing has acquired a longitudinal, and in a few genera a transverse fold, and in most genera a fan-like plaiting of the expanded anal area. Numerous and comparatively strong cross veins, rare in the front wings, and unknown in the hind wings of paleozoic forms, have now become very commonly developed in both wings. Not only have both wings departed more widely from the primitive type, but differentiation between the front and hind wings has increased as well.* The front wings have become, as a rule, more resistant, although there were species in the Carboniferous with wings more opaque than some of the thin-winged living species. Important changes have occurred in the abdomen. The terga and sterna have been modified, tending toward a reduction in the number of abdominal segments. The genital pouch has been perfected, and the ovipositors have become reduced and adapted to perform a specialized function.

The division into coördinate groups, based originally on the differences in the venation of the front wings, was strengthened by the discovery of a well-developed ovipositor in paleozoic forms. More complete knowledge of the second pair of wings brings out additional distinctive characters. In the meantime, forms more or less intermediate are coming to light, and it may be confidently expected that the late paleozoic and early mesozoic will in time yield other intermediate forms. The exact point of disappearance of the Paleoblattidæ and origin of the Blattidæ is at present unknown. The geological age of the Fairplay deposits in South Park, Colorado, which contain the latest forms of the one in association with the earliest of the other,

* See also, Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 31, 1885.

has not been entirely established. Lesquereux, on the evidence of the flora, referred the deposits unhesitatingly to the Permian. Scudder, from a study of the insects, insisted on the Triassic age of the beds. The plants were found to represent several characteristic paleozoic genera. The insects belonged to eight genera, seven of which were cockroaches. Three of the cockroach genera were otherwise known only in the paleozoic, the remaining genera were new and at that time peculiar to the locality. It may not be out of place to add in this connection that the range of cockroach genera, as understood at the present time, is much less contradictory to the evidence drawn from the plants than was supposed when the papers in question were written. Five of these seven cockroach genera are now known to occur in the Coal Measures and Permian, leaving only two peculiar to the Fairplay locality and of Triassic affinity. In view of the occurrence as low down as the Coal Measures of the advanced genus *Schizoblattina*, described above, it would not be surprising to find true Blattidæ as early at least as the Permian, and should the fossil here tentatively identified as an egg case, prove to be such, it must be accepted as evidence of the existence of Blattidæ along with Paleoblattidæ as early even as the Upper Coal Measures. Of the Paleoblattidæ, the Mylacridæ will doubtless be found the older. The broad pronotum with but slightly rounded posterior border, the greater distance of the subcosta from the costal border, and the presence of a branched submarginal costa in the hind wing, all indicate the earlier position of this tribe. The Blattinariæ, on the contrary, are more diversified, continue later, and lead up to more advanced types.

In the course of their development, the cockroaches afford illustration of laws of evolution which may be summarized under the headings: Specialization by reduction; parallel evolution; mechanical principle of evolution; and recapitulation of ancestral characters.

Specialization by Reduction.—The long ovipositor of early cockroaches seems to indicate that a well-developed ovipositor is a primitive character in the Orthoptera, its reduction in the modern Blattidæ being an expression, like the peculiar egg case and genital pouch, of a specialized condition of the external genital organs. In this respect the Gryllidæ and Locustidæ present, no doubt, a closer approximation to the early condition than do the cockroaches, although on the whole the latter seem to be the more generalized. The more or less complete fusion of two or more of the main veins at their base or throughout a part of their course appears to be a second illustration of the law of specialization by reduction.

Parallel Evolution in the Orthoptera.—The plication, so constant a feature in the hind wings of modern Orthoptera, is,

as Scudder maintained, a comparatively recent acquisition. It is to be noted that the plaiting as well as the fold of the hind wing of cockroaches developed subsequent to the differentiation of these insects as a distinct phylum. A comparatively broad anal expanse was, however, common to the early Orthoptera, but the plaiting itself has originated independently in more than one division of the order. The same is true of cross veins. It is probable that at the time cockroaches were differentiated, well-marked cross veins were entirely lacking. Now, on the contrary, cross veins are numerous and not unlike those of other Orthoptera.

Mechanical Principle.—The plications are doubtless developed largely in response to mechanical need. Mechanical principles seem also to have had an influence in developing cross veins.* The interchange of the circulating fluids of the wing, tending to follow within established paths, probably also influenced the development of cross veins.

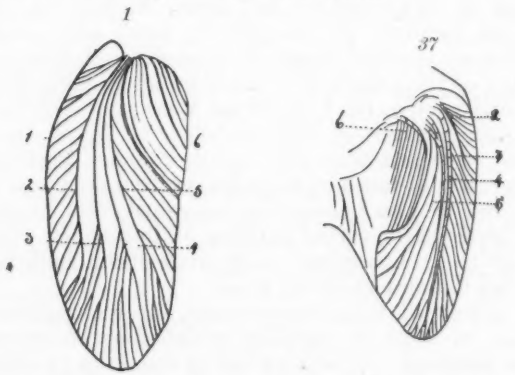


FIGURE 1.—*Gerablattina arcuata* Sellards; illustrating venation of a typical Carboniferous adult cockroach wing.
FIGURE 37.—Wing of a recent nymph; showing venation. (After Packard.)

Recapitulation of Ancestral Characters.—The recurrence during the ontogeny of the individual of characteristics found in the adult condition of earlier representatives of the phylum is familiar to the student of any group. The insects are not an exception to the general rule. In the accompanying figures the nervation of the wing of a modern nymph cockroach is brought into comparison with a typical Carboniferous adult.

*It is interesting to notice an analogous progressive evolution in the vegetable kingdom. The Carboniferous flora contains a great majority of simple veined leaves, while at the present time netted-veined leaves predominate. In the case of plants, both mechanical and physiological factors have doubtless operated.

Homologous veins bear the same number. The close similarity is very apparent. The modern cockroaches thus present in their ontogeny an interesting illustration of the recapitulation of ancestral characters.

EXPLANATION OF PLATE I.

FIGURE 1.—*Mylacris elongata* Scudder. An adult, slightly enlarged. Same specimen as illustrated by Text-figure 8. The head projects in front of the pronotum. The abdomen is noticeably short in comparison with the thorax and long wings.

FIGURE 2.—*Etoblattina mazona* Scudder. Nymph with ovipositor preserved. Same specimen as Text-figure 13.

FIGURE 3.—*Mylacris* (*Dipeltis*) *diplodiscus* Packard, sp. Type specimen. The head projects from beneath the pronotum. The impressions of the first pair of legs are indistinctly seen through the integument. The femora of the second pair of legs can be detected in the photograph. For a line drawing of the specimen, see Text figure 4.

FIGURE 4.—*Etoblattina Hilliana?* Scudder.

FIGURE 5.—*Spiloblattina maledicta* Scudder. sp. The wing shown in this photograph, also in Text-figure 26, is of the form or variety of the species with arched costal border and short cubital area.

FIGURE 6.—*Spiloblattina maledicta* Scudder, sp. Typical wing of the species having slightly arched costal border correlated with great extent of the cubitus. Same as Text-figure 27.

FIGURE 7.—*Gerablattina arcuata* sp. nov. Type specimen. The wing, as the photograph shows, has light and dark areas similar to those of *Spiloblattina*, to which genus possibly the species should be referred. The same specimen is illustrated by Text-figure 1.

FIGURES 8, 9.—*Etoblattina* sp. Detached hind wings. Same specimens as Text-figures 34 and 35.

FIGURE 10.—*Spiloblattina maledicta* Scudder, sp. The hind wing is of thinner texture and has color area similar to those of the front wing.

FIGURE 11.—*Etoblattina coriacea* sp. nov. Same as Text-figure 29.

Figure 1 is but slightly enlarged; Figure 3 is a little less than twice natural size; all others are enlarged approximately two and one-half diameters.

Figures 1-4, from the Coal Measures of Mazon Creek, Illinois; all others from the Upper Coal Measures of Lawrence, Kansas.

Originals of Figures 1, 2, and 4, in the Yale University Museum; of Figure 3, in the National Museum; all others, in the University of Kansas Museum.

ART. XXVII.—*Electrotropism of Roots;* by AMON B. PLOWMAN. (With Plates IX and X.)

IN a brief report published in this Journal last month, the writer gave the more important results of a series of experiments in the field indicated by the above title. These observations extend over a period of more than two years, and have been carried on as a part of a general study of the electrical relations of plants, at the Memorial Research Laboratory of Harvard University. As indicated in the preliminary paper, this particular phase of the work has had for its object the explanation of the behavior of roots growing in the presence of an electrical current.

The general fact of galvanotropic response in roots was established in 1882 by the careful studies of Elfving,* who found that the roots of young seedlings growing in spring-water through which a current of electricity was flowing, almost invariably turned, after a little time, toward the positive electrode. Elfving modified his experiment by using from one to six Leclanché cells in his battery; by varying the distance between electrodes from $2{\cdot}5^{cm}$ to 15^{cm}; by the use of zinc, copper, platinum, and carbon electrodes; and by a study of various plants, including species of *Vicia*, *Zea*, *Secale*, *Hordeum*, *Cannabis*, *Ricinus*, *Cucurbita*, *Tropaeolum*, *Convolvulus*, *Cynara*, *Helianthus*, and several others. He found that throughout all these variations in conditions the results remained practically constant in kind, the roots always turning, sooner or later, toward the positive pole. He observed, also, that the roots were invariably killed by the prolonged action of the current from even a single Leclanché cell.

By way of explanation of his results, Elfving showed that the elongation of a root in the presence of an electric current is approximately only half as great in a period of 12 hours as is that of a similar root growing under normal conditions for the same length of time. Hence it was evident that growth was retarded by the electric current, and the greater retardation on one side than the other of the root was attributed to some unknown property of the root itself. This view of the matter was apparently fully justified by certain results obtained by Elfving in his trials with seedlings of *Brassica* and *Raphanus*. In the former the majority of the roots turned toward the negative pole, while in the latter there was no well defined response in either direction. This would indicate a specific difference which could be attributed only to the protoplasm itself, and it was upon this difference that Elfving proposed to separate plants into two groups, the one positively galvanotropic, the

*Bot. Zeit., 1882.

Fig. 2.

Fig. 3.

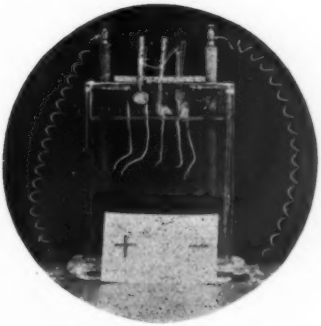


Fig. 1.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

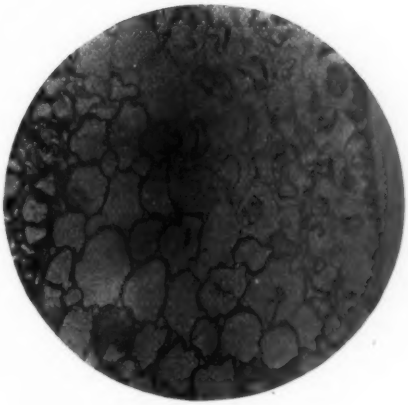


Fig. 10.

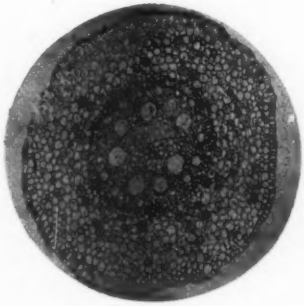


Fig. 8.

Fig. 9.

other negatively galvanotropic. It should be stated, however, that in the earlier part of his paper Elfving observes that galvanotropism is not to be considered a biological phenomenon of the same order as heliotropism, geotropism, and most other common paratonic responses. In accounting for the invariably fatal effects of a long-continued current, Elfving offers the suggestion that the electrolyte is probably rendered toxic by the formation of poisonous compounds at the surface of the electrode.

While Elfving's study of this subject was quite complete and his methods were in general above question, it has seemed desirable not only to repeat his work, but to extend it in a number of lines, in order, if possible, to arrive at some more satisfactory explanation of the results obtained.

The electrical equipment used for these and related studies consists of a battery of "Excelo" cells, a small direct-current dynamo, the 500-volt city power current, and various resistances, rheostats, and measuring instruments. The "Excelo" cell is a combination of the principles of the Daniell cell and the "gravity" cell. This cell is very satisfactory for closed-circuit work, since it maintains a practically constant potential for days or even weeks, especially when only a fraction of the available amperage is used. The dynamo is of the General Electric type, driven by a General Electric 500-volt direct-current motor. The dynamo is rated at 2·5 kw. capacity, at a voltage ranging from 75 to 125 at normal speed, controlled by a field rheostat. A speed-rheostat on the motor permits a considerably wider range of voltage in the dynamo. The 500-volt power-current itself is available for experimental work, through a series of resistances and rheostats. Among the measuring instruments are included a watt-meter, volt-meters, ammeters and galvanometers, one of which is sensitive to 10^{-6} volt. It is possible to obtain from this equipment a fairly complete gradation of measured initial potentials from 500 volts down to 10^{-6} volt.

However, it is not always sufficiently explicit to state merely the difference in potential between the terminal electrodes, since the amount of the current, which is the essential thing, depends quite as much upon the form and conductivity of the electrolyte as upon the initial potential-difference between the electrodes. In other words, it is the density of the current which is of importance in our present investigation. Current density has been variously defined by different authorities,* but it is sufficiently definite for our purpose to consider current

* A. Gray, "Absolute Measurements in Electricity and Magnetism," p. 7, 1888. Oliver J. Lodge, "Modern Views of Electricity," p. 69. 1889. W. E. Ayrton, "Practical Electricity," p. 117, 1887. Clerk Maxwell, "Electricity and Magnetism," § 64, 1881.

density as the amount of current passing a unit cross-section of the conductor in unit time. This, in any case, will evidently depend upon the E.M.F. of the current, the conductivity of the conductor, and upon its sectional area and the distance between electrodes. The unit of current density is the milli-ampere, and the current is of unit density when the conditions of the circuit are such that one milli-ampere of current passes 1^{cm^2} of sectional area of the conductor in one second.

The general method of experimentation has been similar to that followed by Elfving. Fig. 1 (Plate IX) shows one of the vessels used in subjecting roots of seedlings to the action of an electric current. Internally this vessel measures about 5^{cm} wide, 15^{cm} long, and 18^{cm} deep. When in use the cubette is wrapped with black paper in order to protect the roots from the influence of light. In the majority of cases the electrolyte employed has been ordinary tap-water, though as one phase of the study, dilute solutions of a great variety of substances were used. Since the products resulting from the electrolysis of common metallic electrodes such as copper, zinc, tin, etc., are usually highly injurious to plants, it was found necessary to use electrodes of platinum or carbon. The latter material has proved to be entirely satisfactory, and it is to be recommended for its cheapness and convenience. In the small vessel shown in fig. 1, the electrodes are "Electra" arc-lamp carbons, $\frac{5}{8}''$ x $7''$, fitted with binding-posts for connecting the wires. In a larger vessel plate-carbon electrodes were used. These were of high-grade carbon, $\cdot 6^{cm}$ x 4^{cm} x 15^{cm}, each with a binding-screw. It has been shown by repeated experiments that the product of electrolytic decomposition of these carbons is perfectly harmless to plants, even when present in sufficient amount to render the electrolyte quite black.

The seedlings are suspended by glass hooks passing through a sheet of cork which serves as a cover for the vessel. In this way perfect insulation is secured, thereby preventing any passage of current through the root in the direction of its longer axis.

The seeds are first germinated in moist sphagnum, and when the radicles have reached a length of 2^{cm} to 4^{cm}, the seedlings are attached to the glass hooks with their roots pointing directly downward and dipping a short distance into the water in the jar. If left to grow normally in such a situation, some roots will grow directly toward the bottom, while others bend about in a more or less tortuous path. It is a well-known fact that different species of plants show characteristic behavior in this respect. Thus *Pisum sativum*, many varieties of *Zea mais*, and various other plants develop quite crooked roots when grown in water, while other varieties of *Zea mais*, *Lupinus albus*, *Hyacinthus orientalis*, etc., grow long straight roots under these circumstances.

However, if a current of electricity be passed through the

water in which these roots are growing, they almost without exception turn, sooner or later, toward the positive pole. The time required for this reaction depends upon the kind of plant, as well as upon the density of the current. In a uniform current, those plants which show most rapid normal growth of the roots are the ones which show a typical curvature most quickly. For any given kind of root there is a maximum current density at which the curvature is produced most rapidly, while a weaker current requires a longer time to bring about the same results. On the other hand, if the current density be raised even slightly above the specific maximum, the roots are killed before curvature can take place. As is to be expected, this specific maximum differs considerably in different plants, and also for roots of different degrees of maturity in the same plant. Thus the maximum effect is produced in a radicle 2^{cm} long of *Lupinus albus* by a current density of about 1 milli-ampere, while a similar root of *Zea mais* reacts most rapidly in a current of 1·5 milli-amperes. For roots which have reached a length of 12^{cm} or 15^{cm} the maximum current density is less than for the shorter roots, being about ·8 milli-ampere for *Lupinus* and 1 milli-ampere for *Zea;* and the maximum curvature is less rapid than in the case of young roots.

The abruptness of the curvature is dependent chiefly upon the kind of plant and the vigor of the root, but, other things being equal, it appears that the sharpest curves are formed in a current considerably below the specific maximum density. It frequently happens that roots of *Zea mais* are curved through an angle of 90° in a length of 1^{cm} or less, and very young radicles of *Lupinus albus* have been bent through a right angle in a length hardly exceeding twice the diameter of the organ at the middle point of the curve.

Fig. 2 represents a number of young seedlings of various size of *Zea mais*, after being exposed for one hour to a current density of 1·2 milli-amperes. The sharpest curvature in this case is shown by the shortest of the radicles, while the longer ones show a more gradual bending. If a weak current is kept on such seedlings as these for several hours, it is found that the majority of the roots continue to grow horizontally toward the positive pole. The maximum current density invariably kills the roots in a short time, as was observed by Elfving, but it has been found possible to adjust the current to such a strength as not to kill the roots and yet to hold them to their horizontal course against their normal geotropic tendency.

On the other hand, if the current is turned off after an hour, and the seedlings are left in the water for a time, we often obtain such results as those shown in fig. 3. Here most of the roots have continued to curve, in some cases forming complete coils. It has often happened that roots which have been less seriously affected than those shown in fig. 2 will, when removed

from the action of the current, bend downward again near the tip, forming a double curve, and continuing to grow in an altogether normal way again. In such cases there is always developed a conspicuous enlargement of the root at the second, or lower, curve, and a constriction at the first, or upper, one. This constriction is always in the form of a flattening of the concave side of the curve.

The location of the greatest curvature in the root is, as Elfving observed, at the point of most rapid normal elongation. It should be added, however, that the sharpest part of the curve is at the point of most rapid elongation at the time when the current is first turned on. This fact is most strikingly evident in the case of very vigorous roots exposed to a rather weak current. In long roots which are exposed for their whole length to the current, there is but little curvature in the piliferous zone. Hence it appears that the curvature is dependent upon active growth of the cells.

When the seedlings are suspended so that the root-tips just touch the water in the jar, the curvatures are usually different from those developed when the roots are wholly submerged, and the reaction varies more noticeably with change in amount of current. For example, if seedlings of *Lupinus albus* are arranged with roots dipping 1^{mm} or less into the water, and a very strong current, say 10 milli-amperes, is passed for a few minutes, the root-tips soon curl to such an extent as to be lifted out of the water. In a few instances the roots have continued to grow horizontally for several millimeters just above the surface of the water, and toward the positive pole, but they are usually killed at once by a current of this density. With a very weak current the roots do not commonly begin to curve perceptibly until the zone of most rapid elongation reaches the surface of the water, when a prompt response occurs, just as in the case of wholly submerged roots.

When the seedlings are placed with their roots horizontally, or parallel to the path of the current, those which point toward the positive pole continue to grow in that direction, contrary to the influence of the force of gravity, so long as the current is comparatively weak. A stronger current quickly kills these roots, though without producing any curvature in them. The roots pointing toward the negative pole usually bend downward in a perfectly normal manner for a little time, then the curvature becomes very abrupt, and the tips are turned back toward the positive pole. If the current is turned off at this stage, the roots sometimes continue to bend, forming a complete coil, and then growing downward again. It usually happens, however, that the seedlings are killed by this treatment.

Elfving has shown that when an electric current is passed upward through a root the cells are quickly killed, while other roots transmitting a similar current downward are not seriously

affected, even after several hours. This experiment was repeated by suspending two seedlings by hooks of platinum wire, with the roots dipping several millimeters into a vessel of water. The platinum wires are connected through a resistance with the battery, making a circuit downward through the first root, and upward through the second. Under these conditions a ·1 milli-ampere current killed the second root in twelve hours, while the first was not apparently affected. When a ·5 milli-ampere current was passed through the roots for half an hour and then turned off, the second root was greatly checked in its growth, and after a few hours it showed a pronounced bending toward the other root. In every case the prolonged passage of even a very weak current caused a loss of turgor in the parts of the first seedling in the region of the platinum contact, even when the root itself was unaffected.

In comparing the results of these studies with those given by Elfving, it appears that there is substantial agreement in the general fact of response curvatures. The plants examined include practically all those enumerated by Elfving, with the addition of species of *Lupinus*, *Linum*, *Fagopyrum*, *Milium*, *Allium*, and *Hyacinthus*. However, it has been shown that the passage of an electric current through water in which seedlings are growing is not necessarily fatal to the plants, as asserted by Elfving, but that the current may be so weak as not to kill the roots and yet cause them to grow horizontally toward the positive pole.

Moreover, the so-called "negative galvanotropism" mentioned by Elfving does not seem to be a constant property of any species thus far studied. That the usual curvature toward the positive pole is less pronounced and less constant in some species than in others, can not be denied. However, the reverse curvature has not been found to be constant in any case, and even in the most doubtful species it has been possible, by varying the density and time of action of the current, to produce the normal curvature in a majority of the roots.

That Elfving was justified in concluding that galvanotropism is not of the same order of phenomena as heliotropism, geotropism, hydrotropism, etc., is made apparent by the facts just pointed out. The great rapidity of the reaction under certain conditions, and the fact that all but extremely weak currents are very harmful to the plant, seem to indicate the same conclusion. But it must be admitted that so far as the real significance and ultimate explanation of the phenomenon are concerned, no satisfactory solution is offered either by mere external appearances or by the purely biological features of the case.

A comparative study of the internal structure of normal and electrically curved roots has proved highly instructive in this connection. Fig. 4 shows a longitudinal section of the tip of a root of *Hyacinthus orientalis*, which had been acted upon for

half an hour by a current of ·8 milli-ampere density. The side of the root represented by the left-hand side of the figure was directed toward the positive pole. Here the cells are evidently in a state of partial collapse, the protoplasm is contracted, and the thin walls are more or less crushed. On the opposite side of the root there is every indication of a perfectly normal condition of the cells. Fig. 5 is from a longitudinal section of a root of *Hyacinthus orientalis*, after three hours exposure to a ·7 milli-ampere current. This section is taken from a part of root about 14^{mm} or 15^{mm} back of the tip, or at the point where elongation was most rapid at the time when the current was first turned on. It is perfectly evident that the cells on the concave side of this root, or the side toward the positive pole, were killed, while those on the opposite side kept on growing quite normally.

It should be mentioned in passing that when such curved roots are fixed in Flemming's fluid there is always a conspicuous white stripe down the concave side of the root, even after the other parts have turned quite brown or even black. This is an indication of the presence of dead cells in this region. The same thing is often shown in roots while the electric current is still acting upon them, by the fact that the concave side of the root becomes translucent from the escape of cell-sap into the intercellular spaces.

The harmful effects of the current are even more strikingly shown in cross-sections of the curved roots. Fig. 8 represents a transverse section at 10^{mm} from the tip of the root of *Hyacinthus orientalis*, after exposure to a ·7 milli-ampere current for one hour. Here the upper left-hand part of the section was directed toward the positive pole. Fig. 9 is from a section of such a root after two hours action of a similar current. In this case the upper right-hand side was toward the positive pole. Fig. 10 is an enlarged view of a part of the section shown in fig. 9, along the line between the more affected and the less affected parts. A comparison of these with fig. 6, taken from a section of a normal root, shows that there has been more or less shrinkage and collapse in all parts of the curved roots, but that the actually destructive action has been confined to the side toward the positive pole. This partial collapse of the entire structure is not evident in a root exposed to a ·1 milli-ampere current, while a very brief action of a strong current produces this effect in the entire root-tip, as shown in fig. 7, which is from a section of a root of *Hyacinthus orientalis*, treated for five minutes with a 10 milli-ampere current.

From these facts of the minute anatomy of electrically curved roots it seems to be self-evident that the curvature is the result of the paralysis and death of the protoplasm on one side of the structure, resulting in the complete arrest of development in that region, while the other parts go on growing in a more or

less perfectly normal way. As suggested in a former report,* this condition of the root is most satisfactorily accounted for by attributing the effects upon the protoplasm to the direct action of the positive electrons. That the effects are not of an ordinary chemical nature is evidenced by the fact that, so far as is known, the nature and rapidity of the response is conditioned solely upon the density of the current, regardless of the chemical composition of the electrolyte. This conclusion is based upon the results of large numbers of trials with a great variety of acids, bases, and salts, used always, of course, in extremely dilute solution, but giving, nevertheless, a wide variation in the chemical nature of the positive ions. But so long as the current density is kept constant the roots behave in precisely the same manner, regardless of the chemical composition of the electrolyte, provided always that the chemicals are so dilute as not to be directly and immediately harmful to the plants.

Upon the basis of the electron theory all the phenomena of electrotropism are readily and naturally explained. Whenever an electric current flows through an electrolyte, there is a stream of positive electrons flowing from the positive pole to the negative pole, while an equivalent stream of negative electrons flows toward the positive pole. Any object, such as the root of a seedling, dipping into the electrolyte parallel to the electrodes, will have that side toward the positive pole exposed to the stream of positive electrons, while the other side is equally exposed to the negative electrons. Consequently the cells on the side of the root toward the positive pole are sooner or later killed by the positive electrons, while the other side of the root continues to grow more or less vigorously, pushing the tip of the root around in the direction of the positive pole. When the growing end of the root has reached a horizontal position, or has become parallel to the streams of electrons, it is kept in that position, since any deviation would expose the more rapidly growing side to the positive electrons, with a consequent checking of the growth and a return to the horizontal position. The same explanation holds good in the case of roots which are placed originally in the horizontal position with their tips pointing toward the positive pole. That the delicate growing point is not at once killed when thus directed against the destructive stream of electrons is no doubt to be accounted for by the presence of the root-cap, which more or less effectually shields the meristematic tissue for a time at least.

Similarly we may explain the behavior of the seedlings used as electrodes. The positive one is injured only at the point of contact of the platinum wire, where the positive charge enters it. The part dipping into the water is receiving a stream of negative electrons, and consequently is uninjured. The negative seedling, on the other hand, is receiving a stream of posi-

* See this Journal, vol. xiv, p. 131, 1902.

tive electrons through its root, chiefly from the side toward the other seedling, hence it is curved and ultimately killed.

So far as can be made out from these studies up to the present time, the negative electrons are in no case harmful to plant protoplasm; and in several instances a marked acceleration in growth may reasonably be attributed to their influence. However, in the present state of knowledge, it would be imprudent to assert without qualification that negative electrons stimulate vegetable protoplasm.

A study is now being made of the effects of electric light and power-currents upon trees growing near to or in contact with the conductors. The facts thus far collected are in perfect accord with those outlined in this paper.

For the present, the point of principal interest lies in the fact that the phenomenon termed "galvanotropism" by Elfving has its ultimate cause in the effects of the electrons, or electricity *per se*, and apart from any streaming of ions or any ordinary chemical reaction. It is for this reason that the term "electrotropism" is deemed more appropriate than the term "galvanotropism" as used by Elfving.

Aside from their purely biological relations, the results of this investigation are of interest in their bearing upon the theory of ionization and upon the electron theory. For every new problem that is satisfactorily solved by a theory renders that theory more credible; and the problem of electrotropism is certainly of this nature, in its relation to the theories mentioned.

The results of these studies seem to indicate that whatever advantages may be derived from the use of electricity in practical horticulture are to be attributed rather to secondary chemical and thermal effects than to electrical energy as such, except perhaps in cases where the plants are negatively charged.

Harvard University, July, 1904.

EXPLANATION OF THE FIGURES, PLATES IX AND X.

Fig. 1. Cubette jar, with electrical connections, for subjecting roots of seedlings to the action of an electric current. (x $\frac{1}{3}$.)

Fig. 2. Young seedlings of *Zea mais*, after exposure for one hour to the action of a weak current. (x $\frac{1}{4}$.)

Fig. 3. Young seedlings of *Zea mais* which were exposed to the action of an electric current for one hour, then left in the water for an hour without current flowing. (x $\frac{1}{4}$.)

Fig. 4. Longitudinal section of a root-tip of *Hyacinthus orientalis*, which had been subjected to the action of an electric current for thirty minutes. (x 75.)

Fig. 5. Longitudinal section of a root of *H. orientalis*, showing the effect of three hours action of the electric current. (x 75.)

Fig. 6. Transverse section of a normal root of *H. orientalis*, 8^{mm} from the tip. (x 75.)

Fig. 7. Transverse section of a root of *H. orientalis*, 8^{mm} from the tip, after exposure for five minutes to a very strong current. (x 75.)

Fig. 8. Transverse section of a root of *H. orientalis*, 10^{mm} from the tip, showing effect of a moderate current acting for one hour. (x 75.)

Fig. 9. Transverse section of a root of *H. orientalis*, 12^{mm} from the tip, after exposure for two hours to a moderate current. (x 75.)

Fig. 10. A part of fig. 9 more highly magnified. (x 350.)

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *United States Geological Survey.*—The following publications have recently been received :

Professional Papers No. 21.—Geology and Ore Deposits of the Bisbee Quadrangle, Arizona ; by E. L. Ransome, 162 pp., 29 pls., 5 figs.—The lowest rocks of the Bisbee district are pre-Cambrian schists derived from arkose sediments and separated from the overlying Paleozoic beds by a profound unconformity. Cambrian quartzite, 4500 feet of limestone belonging to Cambrian, Devonian, and Carboniferous time, and 4500 feet of Cretaceous sediments constitute the strata represented. Faulting and folding accompanied by intrusions of granitic magmas and by mineralization occurred at the close of the Carboniferous. Later disturbance took place in post-Cretaceous time. The effect of intrusion of granite porphyry is inconspicuous. Faults in this region are numerous and the larger ones are located along a NW.-SE. tract about 2½ miles wide. Certain of the reversed faults are occupied by dikes intruded during the faulting. None of the workable ore deposits occur as lodes or fissure veins. With few exceptions the deposits, from which 400,000,000 pounds of copper have been taken, are irregular replacements of limestone.

No. 22.—Forest Conditions in the San Francisco Mountain Reserve, Arizona; by J. B. Leiberg, L. F. Rixon and A. Dodwell, with an introduction by F. G. Plummer, 91 pp., 7 pls.

No. 23—Forest Conditions in the Black Mesa Forest Reserve, Arizona ; by E. G. Plummer from notes by L. F. Rixon and A. Dodwell, 60 pp., 7 pls.

No. 28.—Superior Analyses of Igneous Rocks from Roth's Tabellen 1869 to 1884, arranged according to the quantitative system of classification; by H. S. Washington, 51 pp. The chemical analyses of rocks published from 1884 to 1900 inclusive, are collected in Professional Paper No. 14. To this have now been added the more reliable and complete earlier analyses. The poor quality of early analytical work is made evident from Doctor Washington's selections. Analyses made previous to 1861 are discarded; of those made between 1861 and 1884 10·24 per cent are retained; and of those made between 1884 and 1900 64·70 per cent are worthy of permanent record. Of 5,303 analyses made between 1861 and 1900 inclusive, 2,112 or 39·83 per cent are classed as superior.

Bulletins. No. 224.—A Gazetteer of Texas; by Henry Gannett, 176 pp., 8 pls. As revised in the second edition the Gazetteer of Texas is a model for such work. Besides the list of place names, data are given regarding soil, climate, education, industries and other geographic elements.

No. 226.—Boundaries of the United States and of the several States and Territories; by HENRY GANNETT, 138 pp., 54 pls. The usefulness of this manual is shown by the fact that two previous editions have been exhausted. The history of all important changes of territory is given, together with a copy of the laws concerning them.

No. 229.—The Tin Deposits of the York Region, Alaska; by ARTHUR J. COLLIER, 57 pp., 7 pls., 5 figs. Tin ore probably of commercial value has been found in widely separated localities in the York region. The ore occurs in alluvial deposits occasionally traced to small veinlets in slate, and in well-defined veins of greisen associated with siliceous intrusions. Mr. Collier gives a valuable general discussion of the occurrence and method of working tin, and adds a bibliography of the subject.

No. 230.—A Gazetteer of Delaware; by HENRY GANNETT, 15 pp.

No. 231.—A Gazetteer of Maryland; by HENRY GANNETT, 84 pp.

FOLIOS. No. 101.—San Louis Folio, California, by H. W. FAIRBANKS. The Coast Ranges of California are exceedingly complex in their geologic structure and students will welcome this description of a typical area. The sedimentary rocks represented belong to Jura-trias, Cretaceous, Neocene and Pleistocene formations, and the igneous rocks, both extrusive and intrusive, date from these same periods except the Pleistocene, and there is in addition a pre-Triassic granite. The igneous varieties represented are granite, diabase, basalt, augite-teschenite, olivine-diabase, quartz-basalt, rhyolite, tuff, pyroxene-andesite, peridotite, pyroxenite, norite, gabbro, andesite-granophyre and dacite-granophyre. The Jura-trias rocks contain molluscan remains not found elsewhere on the Pacific coast. Lens-shaped bodies of jasper occur with the sandstone, and there is an abrupt change from the rock containing siliceous tests of radiolaria to the shallow water formation showing no radiolaria. Abrupt alterations of currents, or depth, or shore line, must have taken place. Lenticles of glaucophane schist from 1 foot to 100 feet in thickness are irregularly formed and ascribed to contact metamorphism. The volcanic eruptions connected with the Monterey shale (Neocene) occurred beneath the sea and consist largely of ash and pumice. The pumice has become so impregnated with pyrite as to form a very resistant rock in which shore terraces are cut. In its topographic development this region presents an interesting study of planation, stream adjustment and of development of a coast line during several periods of elevation and depression. The San Louis valley has been developed by two sets of tributary streams, while the master stream crosses the valley at right angles and enters a canyon. The Salinas is an excellent example of a superimposed stream. It flows in a granite-walled canyon parallel with and a short distance from a wide valley cut in soft rock. Numerous faults are described by

Professor Fairbanks, one with a throw of 2000 feet, yet no fault lines are shown on the map, because "not clearly defined in the field." They are shown, however, in the structure sections and it would be of advantage to students if a less conservative attitude had been adopted in constructing the areal map.

No. 107.—Newcastle Folio, Wyoming–South Dakota; by N. H. DARTON.

No. 108.—Edgement Folio, South Dakota–Nebraska; by N. H. DARTON and W. S. TANGIER SMITH.

The three folios (Nos. 85, 107, 109) which describe the geology of the edge of the Black Hills uplift are interesting, because of their local features, and because they furnish such excellent illustrations of simple monoclines, erosion forms and stream systems. They are destined to be much used in teaching.

No. 109.—Cottonwood Falls Folio, Kansas; by C. S. PROSSER and J. W. BEEDE. This quadrangle is part of the Great Plains province and is underlaid entirely by Carboniferous rock, mostly limestone. The topographic features are due to erosion of nearly horizontal strata.

2. *Geological Survey of Canada.* Summary Report for 1903. 212 pp., 7 maps.—For the year 1903 the staff of the Canadian Survey numbered 57, and Dr. BELL had at his disposal an appropriation of $133,000. Economic work has received chief attention, and parties have been at work investigating mineral resources in Yukon Territory, British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia. Mr. R. W. BROCK describes the Physiography of the Lardeau District, one of the most rugged and picturesque portions of the Selkirks. Dr. R. A. DALY continued his work along the international boundary. He found the conditions exceptionally favorable for structural studies. Three master thrust faults occur. One of them lies in the plane of bedding and the blocks have been rotated and overturned. Additional evidence is found in support of the hypothesis of "overhead stoping" as a mode of igneous intrusion. The work of the survey is retarded by the lack of adequate topographic maps.

3. *Examination of the Coral-Rock Cores from the Borings at Funafuti.*—The general report upon the borings made in the coral rock of the atoll of Funafuti has already been noticed in a recent number (vol. xvii, p. 478, June, 1904); some of the results, however, which have been reached by Prof. J. W. JUDD and Dr. C. GILBERT CULLIS, in the minute chemical and microscopical examination of the cores of coral rock obtained deserve more detailed presentation. It will be remembered that the main boring was carried to a depth of 1114½ feet, while two other minor borings were also made at an earlier date. Samples from the former boring yielded 133 analyses, and those from the latter 72 analyses.

The chief result of this careful chemical work is to show that in the first 50 feet of descent there is a gradual rise in the per-

centage of magnesium carbonate up to 16 per cent; this maximum occurring at depths of 15 and 25 feet, with a falling off between these depths to 12 per cent. From a depth of 25 feet there is a gradual decline in the proportion of magnesium carbonate till 50 feet is reached, where only the normal amount of 1 to 5 per cent is present. This latter relation continues from 50 to 637 feet. From here down, however, the percentage rises rapidly, so that at a depth of 658 feet the proportion of magnesium to calcium carbonate reaches the limit of 40 to 60. This high percentage of 40 per cent is maintained to the bottom* (1114½ feet) with small variation (except for two interruptions to be mentioned), the maximum of 43 per cent being reached at 950 feet. Exceptional conditions were noted twice: between 819 and 875 feet, the proportion of $MgCO_3$ varies widely with a minimum of 4·8 per cent at 826 and a second of 20·6 per cent at 866, and a maximum of 28·5 per cent at 855 feet. Again, between 1050 and 1097 feet there is a falling off, with a minimum of 26·63 per cent at 1061 feet and 30·7 per cent at 1080 feet, and a maximum of 39·4 per cent at 1070. These wide variations remain unexplained.

In regard to other constituents in the rock, it may be briefly stated that the amount of organic matter in the samples examined was found to be extremely small; at depths below 100 feet quite inappreciable; insoluble inorganic matter was also shown to be almost completely absent, as is true in general of coral reef rocks not formed near volcanic masses. The amount of phosphates present was in all cases minute and often quite inappreciable.

The chief interest in regard to the facts stated centers in their bearing upon the important problem of the dolomitization of limestone rocks. This subject is discussed with much thoroughness by Professor Judd. Attention is called to the established fact that the amount of magnesium carbonate present in living corals is small. The greater solubility of the calcium carbonate, however, tends to increase the relative amount. The rapidity of the leaching-out process depends upon the special conditions of temperature and pressure, and further varies widely with different organisms, being greater with those (as the algæ) in which organic matter is present to considerable amount.

This process of leaching-out seems to offer an adequate explanation of the increase in the magnesium carbonate up to 16 per cent, which as stated was observed in the upper part of the cores. The much greater rise in the proportion from a depth of 637 feet to the bottom, reaching a maximum of 43 p. c. at 950 feet, requires another explanation. Here, moreover, as shown by the examination by Dr. Cullis mentioned below, the mineralization, slight above, is prominent, the cores are fairly solid and distinct crystals of dolomite are formed to a greater or less extent throughout the mass.

The author's views can best be presented by quoting his words.

* Normal dolomite calls for 45·65 per cent.

Speaking of the mass resulting from the leaching-out of the calcium carbonate with its enrichment in magnesium, the author adds: "Now this mass in a coral reef is everywhere permeated and acted upon by sea-water containing a very notable proportion of magnesium, principally in the condition of chlorides and sulphates. May not these materials enriched by the magnesium carbonate exercise an attractive action on the magnesium salts of the ocean waters, giving rise to double decomposition and the gradual replacement of a part of the calcium in the carbonates by magnesium." . . . "It by no means follows that, because the dolomite crystals are found only at considerable depth, the action to which the formation of the crystals was due took place only at this depth. The action may possibly have taken place at or near the surface and the rock have subsided after its alteration. At the same time it may be noted that all the rocks now at short distances from the surface in Funafuti show no dolomite crystals and contain only such an amount of magnesium carbonate as may be accounted for by the leaching-out process."

The author adds in closing: "From what has been said, it will be apparent that while the investigations that have been carried on upon materials obtained in the vertical borings of Funafuti and also in specimens obtained from upraised reefs in the Indian and Pacific oceans, show that the dolomitization of coral-reef rock, first demonstrated by the researches of Dana and Silliman, really takes place sporadically over very wide areas, the exact conditions under which the operations occur still call for careful investigation both by observation and experiment."

The mineralogical changes in the cores from the Funafuti borings have been carefully investigated by Dr. Cullis and the results are described with many excellent illustrations in Section XIV of the Report. The discrimination between the three constituents of the coral rock, calcite, aragonite and dolomite, was aided by the use of methods of staining, one of which (after Meigen) served to separate the aragonite from calcite and dolomite, the other (Lemberg) the dolomite from the other species. Speaking generally, it was found that aragonite occurs in the upper cores only and dolomite only in the lower ones (below 637 feet), while calcite, which is the sole constituent of the middle cores, occurs with aragonite above and with dolomite below; aragonite and dolomite were in no case found associated.

The microscopic examination of the cores down to a depth of 637 feet shows the original rock unchanged in the first few feet only; below this point a greater or less degree of alteration has gone on. The changes noted in the first 637 feet include the deposition of secondary calcite and aragonite from solution, the former generally and the latter always in continuity with the same mineral in the original organisms; also the crystallization of the finely divided calcareous detritus and finally the gradual disappearance of the aragonite. As already stated, no individualized dolomite is found in the upper cores even where partial

dolomitization has gone on and the percentage of magnesium carbonate has increased to 16 per cent. Another point of interest is that near the surface masses of dense solid coral rock are common, farther down these are rare and between 220 and 637 feet they do not exist, the material resembling unconsolidated coral reef sand. This difference is explained by the effect of the more complete solution and removal of the original aragonite. When the original rock consisted chiefly of calcite this has been less affected by solvent action and the rock is sufficiently coherent to yield more or less solid cores; when aragonite was more prominent its removal has left the rock in a fragmental and incoherent condition.

A marked change begins with the core at 638 feet; here a large percentage of magnesium carbonate is found, making as before stated a maximum of 43 per cent at 950 feet, and with the exceptions mentioned on p. 240, this condition is maintained to the bottom mineralogically. This means that the cores consist of dolomite, in many cases in the form of distinct rhombohedral crystals, while recognizable calcite has largely or completely disappeared. A feature of the lower cores (from 815 feet down) is the presence of fibrous deposits gradually increasing in relative amount; at first this consists entirely of calcite, at greater depths of alternate layers of calcite and dolomite; in one case (1090 feet) five such layers were observed. Many interesting variations are noted in the microscopic sections in the appearance of the dolomite and calcite and their relations to each other and to the original organisms. These are clearly described and in addition are distinctly presented to the eye in the admirable series of figures, all of which deserve to be carefully studied. Enough has been said, however, to indicate the general conclusions arrived at and to show that this unique investigation serves to throw much light on some of the most difficult problems in connection with the history of the coral reef.

4. *Brief notices of some recently described Minerals.* — Bakerite is a new borosilicate of calcium described by W. B. Giles from the mines of the Borax Consolidated Company in the Mohave desert, 16 miles northeast of Daggett, San Bernardino county, California. It occurs in white, amorphous masses forming veins and nodules of considerable size. In appearance it resembles unglazed porcelain or fine-grained marble; occasionally it has a faint greenish tinge. Hardness = 4·5, specific gravity 2·73. An analysis yielded the following results:

B_2O_3 27·74 SiO_2 28·45 CaO 34·88 H_2O 8·30 Al_2O_3, Fe_2O_3 0·63 = 100.

From this the formula is calculated $6SiO_2 . 5B_2O_3 . 8CaO . 6H_2O$. The mineral is named after Mr. R. C. Baker, a director of the company. It is noted that howlite also occurs in large quantities in the same mines.—*Min. Mag.*, xiii, 353.

Erikite is a new species from the nephelite-syenite of Julianehaab, Greenland, described by O. B. Böggild. It occurs in orthorhombic crystals, sometimes highly modified, of a yellowish

brown to dark grayish brown color. Specific gravity 3·493, hardness 5·5 to 6. The crystals are opaque and under the microscope are seen to have a pseudomorph-like structure consisting of a complex yellow substance of strong double refraction and a colorless one feebly birefringent. An analysis by Chr. Christensen yielded:

SiO_2	P_2O_5	$(Ce, La, Di)_2O_3$	ThO_2	Al_2O_3	CaO	Na_2O	H_2O	
15·12	17·78	40·51	3·26	9·28	1·81	5·63	6·28	= 99·67

The formula of the mineral is doubtful because of the alteration it has undergone. Erikite is named after Erik the Red, who discovered Greenland in 986. The same author gives a further description of the rare species *schizolite* (see this Journal, x, 325, 1900), first described by Winther from the same region in Greenland. It is shown to be triclinic in crystallization and nearly similar in form to pectolite and wollastonite; it is also related to rhodonite and babingtonite.—*Medd. om Grönland*, xxvi, 1903.

Cryolithionite is a new fluoride of aluminium, sodium and lithium described by N.-V. Ussing from the cryolite locality at Ivigtut, Greenland. It occurs in large dodecahedral crystals which are colorless and show distinct dodecahedral cleavage. The hardness is 2·5 to 3 and the specific gravity 2·777. An analysis of purified material gave:

F 60·79 Al 14·46 Na 18·83 Li 5·35 ign 0·36 = 99·79

This leads to the formula $Li_3Na_3Al_2F_{12}$, which corresponds to a cryolite with half the sodium replaced by lithium.—*Bull. Acad. Sci. Lettr. Danemark*, No. 1, 1904.

Thorianite is a new radio-active species from the gem washings at Balangoda, Ceylon, named by W. Dunstan; it has also been observed in pegmatite at Gampola, Ceylon. It occurs in black cubical crystals of specific gravity 9·32. An analysis by G. S. Blake gave the following results:

ThO_2	$(Ce, La, Di)_2O_3$	UO_2	ZrO_2	Fe_2O_3	PbO	SiO_2	
76·22	8·04	12·33	*tr*	0·35	2·87	0·12	= 99·93

The same mineral has been examined by W. Ramsay as to its radio-activity and chemical composition, with results in the latter direction that do not agree with the analysis above quoted.—*Nature*, lxix, 510, 533, 559.

5. *New York State Museum.* 22d Report of State Geologist, 1902. 186 pp., 29 pls.—In addition to the economic work conducted under Dr. Merrill's direction, investigations on the crystalline and Pleistocene rocks were continued.

New occurrences of anorthosite on the Langlake sheet are reported and studied by Prof. Cushing. Prof. Woodworth continued his detailed study of the Hudson-Champlain depression and mapped new shore lines marked by bars, embankments and terraces. Pages 17–41 of the present report is a paper by Prof. H. L. Fairchild on Glacial Waters from Oneida to Little Falls. The history of the Mohawk Valley drainage is divided into three stages: 1. Pre-Iroquois waters—lacustine, and fluviatile, held in

the valley during the ice retreat ; 2. Iromohawk river—draining glacial lake Iroquois and cutting the rock channel at little falls; 3. The Mohawk River.

6. *Observations of a Naturalist in the Pacific ;* by H. B. GUPPY. Vol. I, Vanua Levu, Fiji, xix, 392 pp., 7 plates, 2 maps, 20 figures. London, 1903 (Macmillan & Co.).—This handsome volume describes in great detail the geology and petrography of Vanua Levu. The author concludes that "Vanua Levu is a composite island built up during a long period of emergence, that began probably in the late Tertiary period, by the union of a number of islands of volcanic formation." The platform on which the island rests is supposed to be built up of submarine basaltic flows. The rocks are chiefly basalts and andesites, with a few dacites, trachytes, quartz-porphyries, gabbros and diorites. The author adopts a peculiar classification of his own for these: Classes being based on the ferromagnesian mineral present, the Sub-classes on the presence or absence of groundmass, Orders on the arrangement of the groundmass feldspars, Sub-orders on the ferromagnesian mineral of the groundmass, Sections on the presence or absence of feldspar phenocrysts, Genera on the vitreous or opaque character of these, and Species on their length. There is no discussion of the reasons for the adoption of this classification, criticism of which is uncalled for here. Although the rocks are described petrographically in great detail, not a single chemical analysis of them is given. A chapter is devoted to the magnetic characters of the volcanic rocks, many of which are stated to show marked polarity. Vol. II will deal with the dispersal and distribution of Pacific plants. H. S. WASHINGTON.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Elements of Algebra for Beginners;* by GEORGE W. HULL, 159 pp. American Book Company.—This little book has been prepared for young pupils as a substitute for some of the later work in arithmetic. It does not afford a basis of instruction adequate for preparation for college examinations, nor does it aim to do so. For teaching the technique of algebra, the book is admirably adapted, though in some cases, notably in evasion of negative numbers, the aim for simplicity runs counter to sound science. The collection of examples includes many simple ones carefully graded. H. E. H.

2. *Elementary Algebra ;* by J. H. TANNER. American Book Company.—This book is adequate for the preparation of students for the examinations in Elementary Algebra for any college or scientific school. The development of the numbers used in algebra is careful, and the most striking feature of the book. To a class of somewhat mature students, the book would undoubtedly be of value. H. E. H.

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